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CERTIFICATE OF MAILING

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By: Bonnie HARDIN Mitchell
Bonnie Hardin Mitchell
(Signature)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Sanders, et al.	:
	:
Serial No. 09/966,551	: Customer Service Center
	: Initial Patent Examination Division
Filed: September 26, 2001	: (703) 308-1202
	: Confirmation No. 5266
For: **LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT**	:
	: Attorney's Docket 26272/04003

RENEWED PETITION TO ACCORD A FILING DATE

Assistant Commissioner of Patents
Office of Petitions
Washington, DC 20231

Sir:

This is a renewed petition to accord a filing date of September 26, 2001 for the above referenced patent application. By this Petition, Applicant respectfully submits additional evidence not previously considered by the U.S. Patent and Trademark Office, which is believed to establish with the required reasonable certainty that the U.S. Patent and Trademark Office received Applicant's patent application, complete with claims, on September 26, 2001. This renewed petition is filed in response to the U.S. Patent and Trademark Office's Decision on Petition mailed on March 7, 2002. That Decision dismissed Applicant's earlier Petition filed on November 7, 2001. The Decision was based upon lack of sufficient evidence to establish with reasonable certainty that at least one claim was located upon the application papers filed on September 26, 2001.

Applicant respectfully requests favorable reconsideration of this petition based upon the additional and substantial evidence submitted herewith, so that the application is accorded a filing date of September 26, 2001.

The basis for this renewed petition is the submission of additional evidence in the form of:

1. A Declaration by James A. Rich, the attorney who prepared and submitted the patent application to the U.S. Patent and Trademark Office, that the application contained at least one page of claims (attached hereto as "Exhibit 1");

2. A Declaration by Attorney Rich's assistant, Joyce Ford, who prepared drafts of the patent application which included several pages of claims and other materials mailed to the U.S. Patent and Trademark Office (attached hereto as "Exhibit 2"); and

3. A true and accurate copy of the return receipt postcard indicating that the application was filed with 36 pages, which included at least one page of claims, and was received in the U.S. Patent and Trademark Office ("PTO") and received a filing date of September 26, 2001 (attached hereto on the first page of "Exhibit B").

Applicant has filed this renewed petition after receipt of the Decision Dismissing Applicant's Petition. Applicant had promptly filed the earlier petition on November 7, 2001, after the receipt of a Notice of Incomplete Nonprovisional Application mailed on October 26, 2001.

The following are true and accurate copies submitted pursuant to 37 CFR §1.10(e):

1. A true and accurate copy of the prosecution file of the attorneys of record of the originally deposited patent application containing 18 pages of specification, 2 pages of claims, a single page Abstract, and 14 sheets of drawings, entitled "Low Sonic Boom Inlet For Supersonic Aircraft", filed on September 26, 2001 and bearing Express Mailing Label No. EL084647715US, and which is attached hereto as "Exhibit B";

2. A true and accurate copy of the return receipt postal card showing receipt of these papers by the PTO as of September 26, 2001, which was date stamped September 26, 2001 and which is attached hereto on the first page of "Exhibit B";

Based upon the foregoing evidence, Applicant has established with reasonable certainty that a true and accurate copy of the above referenced patent application which was mailed by Express Mail on September 26, 2001 contained at least one claim. Applicant therefore has traversed all grounds for the dismissal of the prior petition. In the event a fee is required, it is respectfully requested that any required fee be charged to deposit account 03-0172. A duplicate of this petition is enclosed.

In the event there are questions concerning this petition, please contact the undersigned.

Respectfully submitted,

Date: 5-23-02

June Rickey

June E. Rickey, Esq.
Reg. No. 40,144
Calfee, Halter & Griswold LLP
800 Superior Avenue, Suite 1400
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Bonnie HARDIN-MITCHELL
(Typed or printed name of Sender)

Bonnie Hardin Mitchell
(Signature)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Sanders, et al.

Serial No. 09/966,551

Filed: September 26, 2001

For: **LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT**

Attorney's Docket 26272/04003

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Assistant Commissioner of Patents
Office of Petitions
Washington, DC 20231

Declaration of James A. Rich, Esq.

1. I, James A. Rich, was one of the original patent attorneys of record for Calfee, Halter & Griswold LLP in the above-mentioned patent application, and am now a patent attorney with D. Peter Hochberg Co., L.P.A.

2. On September 26, 2001, I prepared a nonprovisional application which claimed priority to the prior provisional application No. 60/235,359. This prior provisional application had one page of claims. A true and accurate copy of the provisional application is attached hereto as Exhibit A.

3. During the normal business hours of September 26th, my assistant, Joyce Ford, prepared various materials to support the patent application filing process based upon the materials completed as of the close of normal business hours. The materials prepared by Joyce Ford included:

A Utility Patent Application Transmittal form which indicated 22 pages of Specification, Claims, and Abstract and 14 sheets of Drawings for a total of 36 pages; A Fee Transmittal Form, An Application Data Sheet and a return postal card indicating 22 total application pages, but failing to include the 14 sheets of Drawings.

4. Due to a variety of factors, the application specification was not completed by me prior to the close of normal business hours on September 26th. As a result, I personally completed and filed the nonprovisional application claiming priority from the prior provisional application after normal business hours. As part of my completion of the application I edited the specification, which resulted in the specification, claims, and abstract containing 21 pages instead of the 22 pages provided at the close of normal business hours.

5. I have enclosed a true and accurate copy (attached to this Declaration as Exhibit B) from the attorney prosecution file of the above referenced patent application which was made and submitted by me on September 26, 2001.

6. As shown on the last page of the patent application transmittal, I signed my name on September 26, 2001. It is the practice of the patent attorneys of Calfee, Halter & Griswold LLP to review all of the documents being forwarded to the U.S. Patent Office on the date they are mailed. My review and signature were conducted and made after normal office hours. As part of my review I noted and corrected the postal card to include the 14 sheets of drawings, and indicated by hand that the application included 36 total pages (which was 22 pages plus 14 pages). My new hand written total did not take into consideration that the application Specification had been reduced as a result of my edits to 21 pages instead of 22 pages. While my total page count on the Utility Application Transmittal Form and return postal card included an overage of 1 extra page (36 pages instead of 35 pages (or 21 pages of Specification plus 14 Sheets of drawings)), no pages were ever missing.

7. As the patent application was completed after normal office hours, I personally made a complete copy for the prosecution file of the above referenced patent application, postcard and transmittal papers which were submitted to the U.S. Patent office on September 26, 2001.

8. To the best of my knowledge and belief, the application submitted to the U.S. Patent Office via Express Mail on September 26, 2001 is identical to the copy in our prosecution file, and contained at least one claim, and in fact included 2 pages of claims.

9. The attorney file copy of the submitted patent application attached hereto (Exhibit B) contains 18 pages of specification, 2 pages of claims, a one page abstract of the

submitted patent application and 14 sheets of drawings. The attorney file copy of the patent application has a total of 35 pages of specification including claims, abstract and drawings.

10. The attached copy of our return postal card (page 1 of the attached copy of the Application) indicates that the Application, with drawings, had 36 pages. As set forth above, I amended the return postal card by hand to indicate the Application had 36 pages (22 pages of specification, claims and abstract, as stated in the Utility Patent Application Transmittal Form, prepared earlier in the day by my assistant Joyce Ford, plus 14 drawing pages) while assembling the papers for submission to the Patent Office on the evening of September 26th.

11. The return postal card copy together with the true and accurate copy of the submitted application from our prosecution file demonstrates that the Application, as submitted on September 26th, contained at least 21 pages of specification, claims and abstract, together with 14 pages of drawings. The specification, without claims, is 18 pages long, and the abstract was 1 page long. Since at least 21 pages of specification, claims and abstract were submitted, there must have been at least 2 pages of claims submitted, as exhibited by the true and accurate copy of the originally filed application provided herewith.

12. I hereby declare that all statements made hereon of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: May 23, 2002

James A. Rich, Esq.
Reg. No. 25,519

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PATENT & TRADEMARK OFFICE

PTO/SB/16 (2-98)
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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)

Given name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Bobby W.	Sanders	2806 Wakefield Lane Westlake, OH 44141

☒ Additional inventors are being named on the 1 separately numbered sheets attached hereto

TITLE OF THE INVENTION (280 characters max)

LOW SONIC BOOM SUPERSONIC CRUISE INLET

CORRESPONDENCE ADDRESS

Direct all correspondence to:

☐ Customer Number [ ] → Place Customer Number Bar Code Label here

Type Customer Number here

OR

☒ Firm *or* Individual Name	James A. Rich, Esq. Calfee, Halter & Griswold, LLP
Address	Suite 1400
Address	800 Superior Avenue, N.E.
City	Cleveland | State: Ohio | ZIP: 44114
County	Cuyahoga | Telephone: 216-622-8636 | Fax: 216-241-0816

ENCLOSED APPLICATION PARTS (*check all that apply*)

☒ Specification *Number of Pages* 12

☐ Small Entity Statement ________

☒ Drawing(s) *Number of Sheets* 8

☐ Other (specify) ________

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (*check one*)

☐ A check or money order is enclosed to cover the filing fees

☒ The Commissioner is hereby authorized to charge any additional filing fees or credit any overpayment to Deposit Account Number: 03-0172

FILING FEE AMOUNT ($): $150.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No

☐ Yes, the name of the U.S. Government agency and the Government contact number are: ________

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Respectfully submitted,

SIGNATURE [signature]

Date September 8, 2000

TYPED or PRINTED NAME James A. Rich

REGISTRATION NO. *(if appropriate)* 25,519

Docket Number: *26272/04003*

TELEPHONE: (216) 622-8636

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PROVISIONAL APPLICATION COVER SHEET

Additional Page

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PTO/SB/16 (2-98)
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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Docket Number	26272/04003	Type a plus sign (+) inside this box→	+

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Lois J.	Weir	1306 Lipton Avenue, S.W. North Canton, OH 44720

Number 2 of 2

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Date of Deposit: 9/26/2000

I hereby certify that this paper or fee is being deposited with the United States Postal Serv[illegible] Mail Post Office to Addressee" service un[illegible] on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

ANGELA SIBER

Name of Person Signing (Type or Print)

Signed: Angela Siber

+

LOW SONIC BOOM SUPERSONIC CRUISE INLET

Field of Invention

This invention relates to intakes for supersonic flow and to air intakes for aircraft that are designed to fly at supersonic speeds.

Background of Invention

The purpose of the supersonic inlet component of the propulsion system for a high speed supersonic aircraft is to efficiently decelerate the approaching high speed airflow to speeds that are compatible with efficient turbojet engine operation and to provide optimum matching of inlet and engine airflow requirements. Entrance airflow speeds to existing airbreathing engines must be subsonic; therefore, it is necessary to decelerate the airflow speed during supersonic flight. Typically, engine entrance Mach numbers for supersonic propulsion systems are 0.3 to 0.4. The inlet must reduce the velocity of the approaching airflow to these subsonic levels while maintaining a minimum of loss in freestream total pressure and while maintaining a near-uniform flow profile at the engine entrance.

In aircraft propulsion systems having supersonic inlets, it is essential that the inlet diffuse the air in a manner to minimize the pressure losses, cowl and additive drag, and flow distortion. For supersonic inlets, efficient deceleration of the supersonic velocities is accomplished by a series of weak shock waves or isentropic compression, in which the speed is progressively slowed to an inlet throat Mach number of about 1.30. A terminal shock wave is positioned at the throat to reduce the velocity to a high subsonic level. The speed of the airflow is additionally slowed in the subsonic diffuser of the

inlet by a smooth transitioning of the flow duct from a smaller throat area to the larger area at the engine entrance.

Mixed-compression inlets, in which some of the supersonic compression or deceleration in velocity is accomplished external to the duct and some of the compression is accomplished internally, have commonly been proposed for supersonic aircraft that cruise at a Mach number higher than 2.0. Any inlet that accomplishes some of its compression internally is subject to an undesirable phenomenon known as inlet unstart. Inlet unstart is characterized by an expulsion of the inlet terminal shock with an associated large increase in drag and large thrust loss. Unstart may also affect the aerodynamics of the aircraft. The technical challenge for the inlet designer is to provide a high performance configuration that provides large operability margins (terminal shock stability), and to also deliver a design that offers a reduction in the overall sonic boom signature of the aircraft. Mixed-compression inlets can efficiently decelerate the airflow while providing large operability margins. However, the external compression, which is provided by a centerbody or cowl surface, radiates shock waves outward that contribute to the aircraft's sonic boom signature. These designs also have leading edges that include an external surface at an angle to the local airflow. Oblique shock waves are generated by these surfaces, contributing to the overall sonic boom problem. An economically viable supersonic commercial aircraft must be able to operate supersonically over land. Over-land operation requires that the sonic boom signature from the aircraft be reduced to acceptable levels. In order to achieve the required acceptable boom levels, sonic boom contributions from each component on the aircraft must be reduced to the lowest possible level. The design of a low sonic

boom aircraft therefore requires an innovation in supersonic inlet design. All-internal compression inlets are desirable from a sonic boom reduction standpoint, because there are no oblique shock waves generated by an external compression system that contribute to sonic boom signature. Additionally, they allow all of the external nacelle surfaces to be completely or very nearly aligned with the external flow (zero external surfaces angles). These low profile external surfaces do not produce a shock wave that contributes to the sonic boom problem. Previous attempts at the development of internal-compression inlets have been generally unsuccessful, primarily due to instability of the terminal shock. The innovative application of a shock stability bleed system can prevent inlet unstarts caused by both internal and external flow disturbances, and provide large shock stability margins, thereby making the internal-compression inlet feasible for application to supersonic cruise vehicles.

An inlet shock stability system consists of bleed regions that duct bleed airflows to variable area exits. The stability system incorporates either passive or active exit area controls. This system prevents inlet unstarts by removing airflow through a large open throat bleed region to compensate for reductions in diffuser corrected airflow demand. Because the stability bleed is not removed until the inlet terminal shock moves upstream over the bleed region, the necessary normal shock operability margin is provided without compromising inlet performance (pressure recovery, and distortion). Previous research has demonstrated that the utilization of a variable bleed exit on a large open throat bleed region can provide very large inlet stability margins for both internal and external airflow variations. The appropriate placement of a stability bleed

system in the throat of an internal-compression inlet makes the design of such a configuration feasible.

Summary of the Invention

This invention provides a revolutionary inlet for supersonic propulsion systems. This inlet contributes minimally to the sonic boom signature of the flight vehicle, but still achieves very high performance and maintains large operability margins through the implementation of a shock-stability bleed system. The unique feature of this design is the utilization of an all-internal compression scheme combined with a shock stability system. This type of inlet offers the opportunity to consider 0° (flow-aligned) external surfaces that will not produce shock waves and the associated sonic boom. Inlets of this type (axisymmetric or 2D) accomplish all of the supersonic compression on the cowl since they do not employ a centerbody.

This inlet system can be used on propulsion systems for supersonic and hypersonic commercial and military aircraft, and on propulsion systems for supersonic and hypersonic missiles. Other features and advantages of this invention will become apparent to those who are skilled in the art after reading the presented specification and the accompanying drawings.

Drawings

Figure 1 is a sketch of an inlet embodying this invention.

Figure 2 is another sketch of the inlet illustrated in Figure 1, with cross-sectional views at varioius points along the inlet.

Figure 3 presents side and top view of the inlet shown in Figures 1 and 2.

Figure 4 is an orthogonal view of the inlet shown in Figures 1 through 3.

Figure 5 is a sketch, in side elevation, of parts of a shock- stability bleed system for this invention. Cross-sections A-A, B-B, and C-C illustrate the porous bleed surfaces, and the detail view illustrates one variable cowl geometry.

Figure 6 illustrates the cowl variable geometry system of Figure 5 in the off-design position.

Figures 7 and 8 are cross-sectional and orthogonal detail views, respectively, of the variable cowl system illustrated in Figures 5 and 6.

Figure 9 illustrates external surfaces that may be used for the inlets of this invention, and shock waves produced with these surfaces.

Detailed Description

The inlet 1 illustrated in Figure 1 has internal cowl surfaces 2 at top and bottom, and internal sidewalls 14 and 15 (downstream view). The inlet external surfaces are 16, 17, 18, and 19. The inlet 1 uses a low-angle (relative to the incoming airflow) initial compression wedge 3 on the internal cowl compression surface 2, which generates an initial oblique shock 4. This internal cowl compression surface 2 includes the initial low angle wedge 3, an isentropic contour 5, a throat section 6 (minimum cross-sectional area), and a subsonic diffuser 7. The isentropic compression contour 5 provides the additional required supersonic compression from the initial wedge 3 to the inlet throat section 6. The isentropic compression flow field is depicted by the Mach waves 8. A normal (terminal) shock 9 is located at the inlet throat 6, across which the flow becomes subsonic. The airflow continues

to decelerate in the subsonic diffuser 7 that extends from the inlet throat 6 to the diffuser exit 10. The inlet duct is rectangular to a location just downstream of the inlet throat 6 and then transitions to a circular cross-section at a station just upstream of the engine location 10. The preferred duct cross-sectional shape transition would be accomplished by filleting the corners of the rectangular cross-section with circular arcs 20 as shown in figure 2. Cross-sections of the inlet duct are depicted in figure 2. The tangent line 11 resulting from the intersection of the flat sidewalls 14/15 and the transition arc 20 is shown in figures 1 and 2 by the straight lines from the cowl surface to a point on the inlet axial centerline just upstream of the engine. The basic design problem of providing low external surface angles for lower Mach number inlets is that the ratio of inlet capture area to engine face area gets smaller as the inlet design Mach number decreases. For the Mach 2.4 inlet design presented in this patent disclosure, which provides an engine entrance Mach number of 0.3, this area difference results in the slight external bulge 13 that is evident beyond the rectangular cross-section in the front view of the inlet in figure 1. This bulge 13 is located at the engine face. For the proposed design, the external surface is transitioned over a very long length on the nacelle upstream of the bulge 13, allowing a very small external angle and minimizing the resulting shock strength. The utilization of an engine that is designed to accept higher entrance Mach numbers would result in a smaller area at the engine entrance, and thus would eliminate bulge 13. The inlet is rectangular at cross-section A-A. The contouring for the engine bulge 13 can be seen on the top 16 and bottom surfaces 17 of cross-section B-B. The inlet cross-section begins to transition to round on both the inside duct corners 20 and on

the external surface corners 21 in cross-section C-C. The transition to a round engine and nacelle is complete for cross-section E-E. The inlet has an opening 12 to allow a typical inlet overboard-bypass system to be installed (figure 1).

As shown in figures 1 and 2, this proposed all-internal compression 2D inlet has top 16 and bottom 17 external surfaces with exterior angles of 0°. It also offers very low external angles on the side surfaces 18 and 19 of the inlet. Low external angles for the sides are probably acceptable, since the shocks will radiate sideways and not downward toward the ground. The external surfaces are more evident in figures 3 and 4. A side view is presented at the top of figure 3 and a top view is presented at the bottom. In the side view, the flat sidewall 19 extends downstream to a location at which the rectangular surface is transitioned 21 to round at the engine face. The leading edge 22 of the sidewalls 18 and 19 includes a 0° internal angle and a very small external angle that is compatible with low sonic boom. In the top view of the inlet, the flat cowling 16 also extends downstream to the transitioning surfaces 21. The top view indicates the transitioning of the bulge 13 created by the larger engine. These surfaces and the transitioning to the round engine nacelle are also shown in the isometric view of the inlet presented in figure 4.

This inlet utilizes a significant amount of isentropic compression. The benefits of isentropic compression and a throat Mach number of 1.3 will result in excellent total pressure recovery. In addition, the overall reduction in performance due to boundary layer will be lower than that of a conventional mixed-compression inlet, since the inlet of this disclosure does not employ a centerbody. Inlets must provide a range of mass flows over which they can operate without the

occurrence of an inlet unstart. Traditional performance boundary layer bleed systems can provide only a small operability margin. Since this margin is generally not sufficient, additional margin is provided by operating at reduced performance levels. A very high level of performance and an adequate operability margin to prevent inlet unstart can be realized through the utilization of a stability bleed system. This system allows operation of the inlet at the optimum performance condition, and yet provides significant shock stability margins. An inlet throat stability bleed system is shown in figure 5. Distributed porous bleed is the preferred method to remove bleed airflow; however, any type of bleed opening can be used. For the preferred configuration, porous bleed surfaces are located in the inlet throat section. Cowl bleed regions 23 are located in cowl section 29, and sidewall bleed regions 24 are located in sidewalls 14 and 15 (see views B-B and C-C in figure 5). In the preferred embodiment, the open bleed regions 23 and 24 consist of the inlet surfaces with 0.125 inch holes drilled normal to the surface to obtain 40% open area (40% porosity). The bleed holes are located on 0.1875-inch centers with the holes in adjacent rows staggered to obtain a uniform distributed pattern. The preferred bleed surface would include a surface thickness to hole diameter ratio of 1.0. The sidewall bleed 24 extends beyond the design cowl position so that bleed can be removed during off-design operation. Folding compartment seals 44 are used to direct the inlet bleed from the bleed surfaces (23 or 24) to exit passages and controls. A stability system employs fast-acting valves, either active or passive, at the bleed plenum exit to control the amount of bleed that is removed from the inlet. These exit area valves that are normally designed to maintain a near-constant pressure in the bleed system are not presented in these figures.

The basic cowl variable geometry is also shown in figure 5. In the figure, three hinge locations 25, 26, and 27 are shown; however, the number of hinges may be any number suitable to provide proper cowl geometry at off-design conditions. The variable cowl consists of an upstream section 28 hinged (25) at the upstream station and connected to additional cowl sections 29 and 30 with hinges 26 and 27, with the downstream end of the last section 30 including a guide pin 31 in a groove 32 (detail) to allow the length change for off-design operation, figure 5. The track 32 for the guide pin is aligned to properly position the downstream end of the last cowl section. All cowl sections are hinged to the first cowl section 28. A sketch of the cowl in the off-design position is presented in figure 6. Note the change in position of the downstream guide pin 31 between figures 5 and 6.

Details of one potential cowl variable geometry scheme are presented in figures 7 and 8. Hydraulic actuators 43 would be utilized to collapse the cowl surfaces for off-design operation. These cylinders would be pinned 45 to bracket 33 that is attached to the outside surface 16 or 17 at one end and pinned at the other end to bracket 34 that is attached to cowl surface 29. The hydraulic cylinders would be attached to a common fluid supply source so that uniform movement could be obtained. Two actuators are shown in figure 8; however, any number could be used that would fit within the space available and effect the desired movement of the cowl surfaces. While the hydraulic actuators provide the actuating power, the actual movement of the second cowl section 29 will be controlled by a scissors arrangement that provides parallel positioning of the section for any operating condition of the inlet. Figure 7(a) shows that this scissor arrangement is comprised of link bars 35 and 36

that are pinned 37 and 38 to brackets 39 and 40 at the outer ends and pinned to frame 41 at pin 42. Frame 41 is also shown in the isometric sketch of figure 8. The off-design position of the cowl 29 is shown in figure 7(b). As indicated in a comparison of the cowl vertical positions between figures 7(a) and 7(b), the inlet throat surface can be actuated to provide a significant increase in duct area for off-design operation. The parallel throat sections 29 at design and off-design can be seen by comparing the cowl 29 position in the figures 7(a) and 7(b).

To minimize sonic boom contribution, all external surfaces 18 and 19 (figures 1 through 4) that must have an external angle greater than 0° (relative to the local freestream flow) are best designed as shown in figure 9 by contouring the surfaces to allow expansion 49 to reduce the shock strength. As indicated in figure 9, the initial surface 18 is at a selected angle 47. After sufficient thickness is achieved, the surface is gradually turned to create the expansion fan 49 that will mitigate the strength of the shock 48 generated by the leading edge angle 47.

The inlet defined in figures 1 through 9 represents a new approach to inlet design. It offers inlet design options that can lead to new more efficient, safer, more environmentally friendly aircraft. The inlet may offer integration options that were not possible with more traditional configurations. This approach can provide an inlet configuration that will provide enabling technology for a quiet (low sonic boom), efficient, supersonic cruise aircraft.

While a 2-dimensional inlet configuration has been described in figures 1 through 9, it will be evident to those skilled in the art that the concept may be extended to the design of internal-compression axisymmetric inlets with similar attributes and benefits.

It is understood that the invention is not limited to the specific embodiments herein illustrated and described, but may be used in other ways without departing from its spirit. Other embodiments of the internal compression inlet described herein that suggest themselves to those skilled in the art are intended to be covered by the claims of this disclosure which are as follows:

We claim:

1. A supersonic inlet employing an all-internal compression system, for which all external surfaces are aligned or very nearly aligned with the external flow in order to minimally contribute to the sonic boom signature of an aircraft.

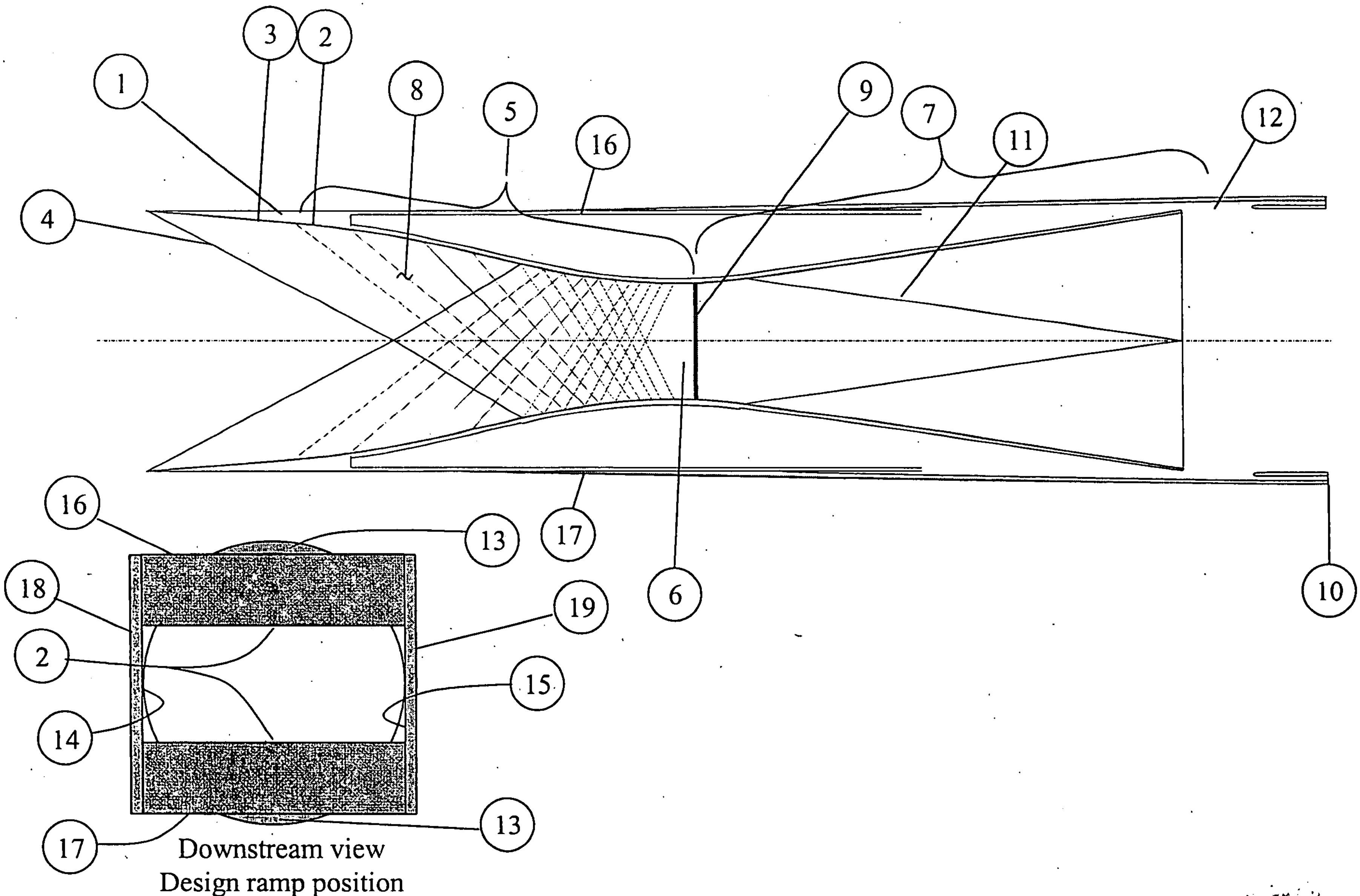
2. An inlet according to claim 1, which employs a stability bleed system to provide terminal shock stability and operability.

3. An internal compression inlet with a shock stability system according to claims 1 and 2, which may be either two-dimensional or axisymmetric in nature.

4. An internal compression inlet with a shock stability system, according to claims 1 through 4, which employs variable cowl surface geometry in order to match the propulsion system's off-design mass-flow demand schedule.

5. An internal compression inlet with a shock stability system, according to claims 1 through 4, for which all external surfaces that are not aligned with the flow consist of a small initial surface angle, followed by distributed expansion of the surface to mitigate the strength of the shock wave generated by the initial angle.

6. An internal compression inlet with a shock stability system, according to claims 1 through 5, which may be installed in any configuration, including pod mounting, surface mounting, and flush mounting on the aircraft wing or fuselage.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Downstream view
Design ramp position

Figure 1

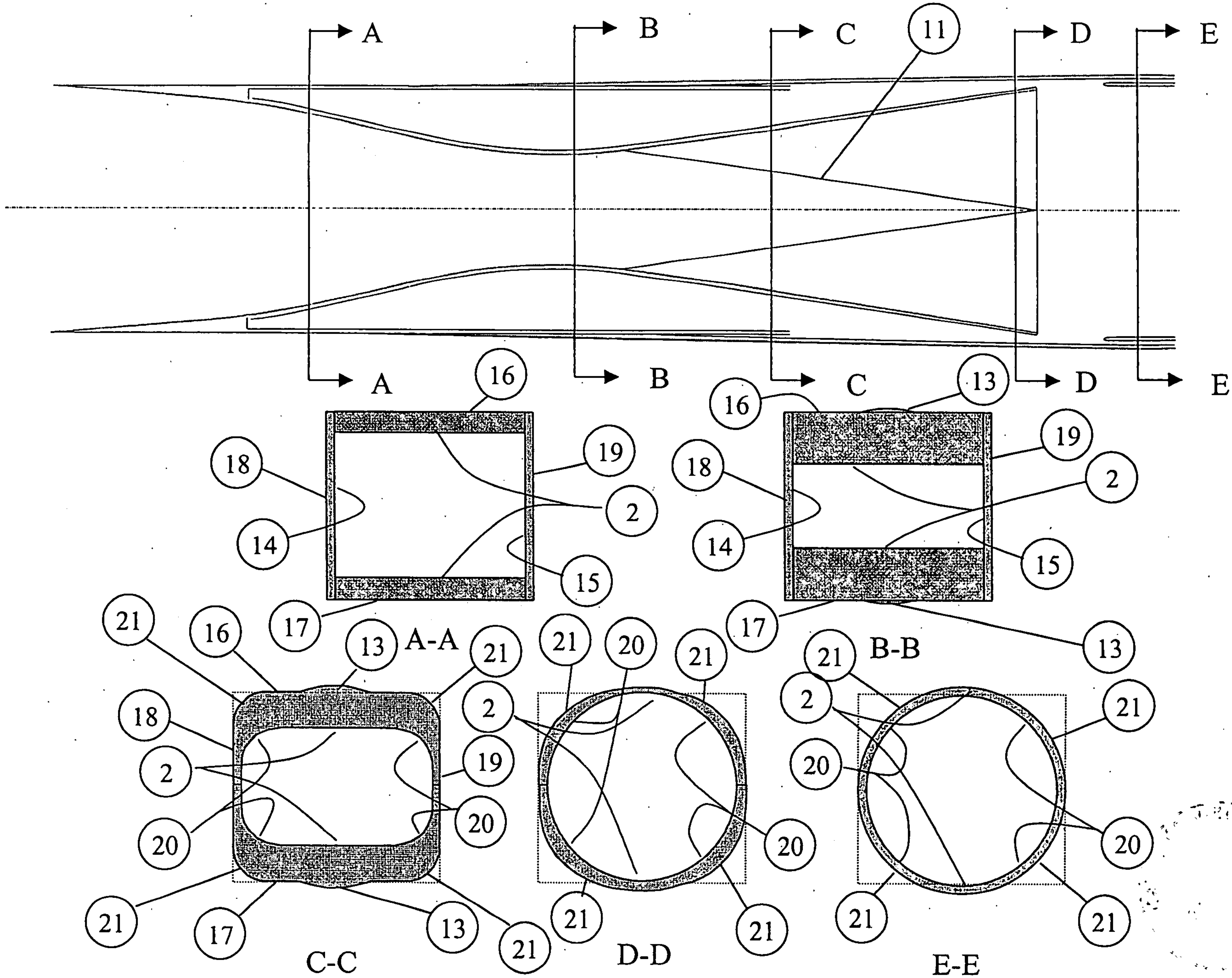
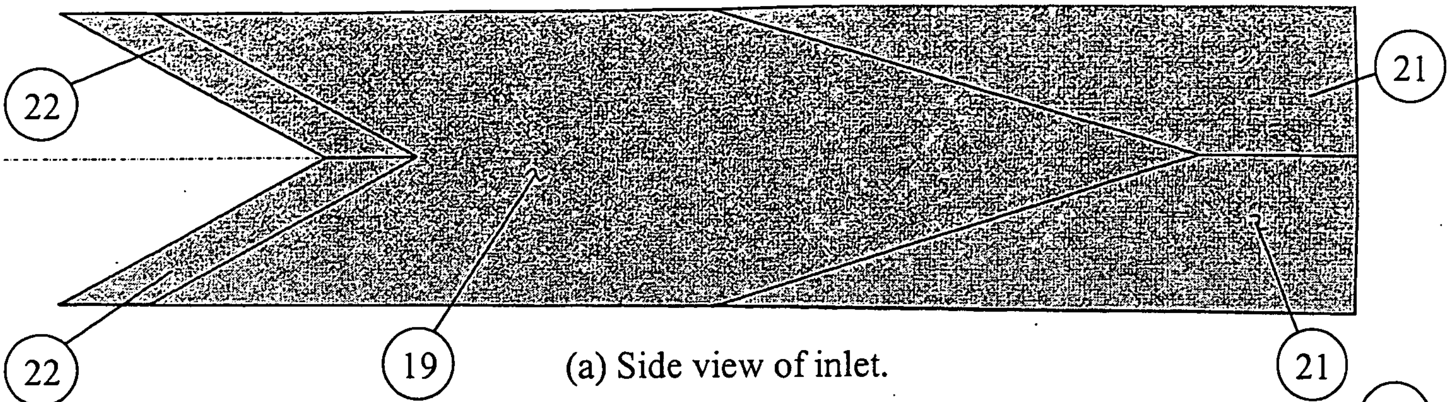
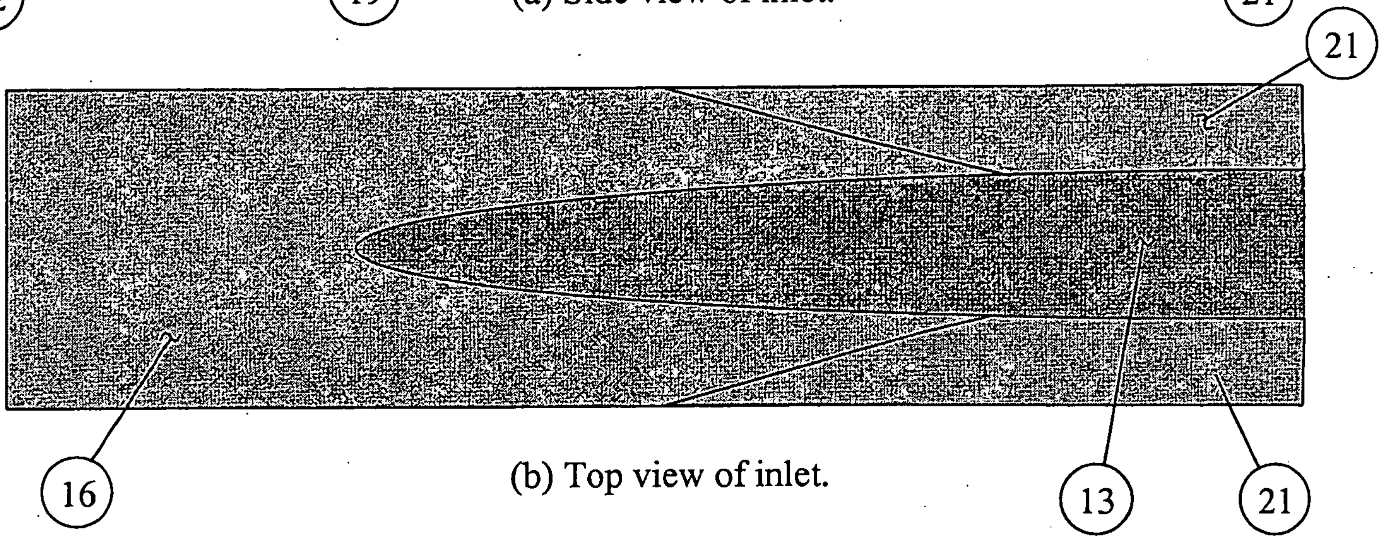


Figure 2



(a) Side view of inlet.



(b) Top view of inlet.

Figure 3

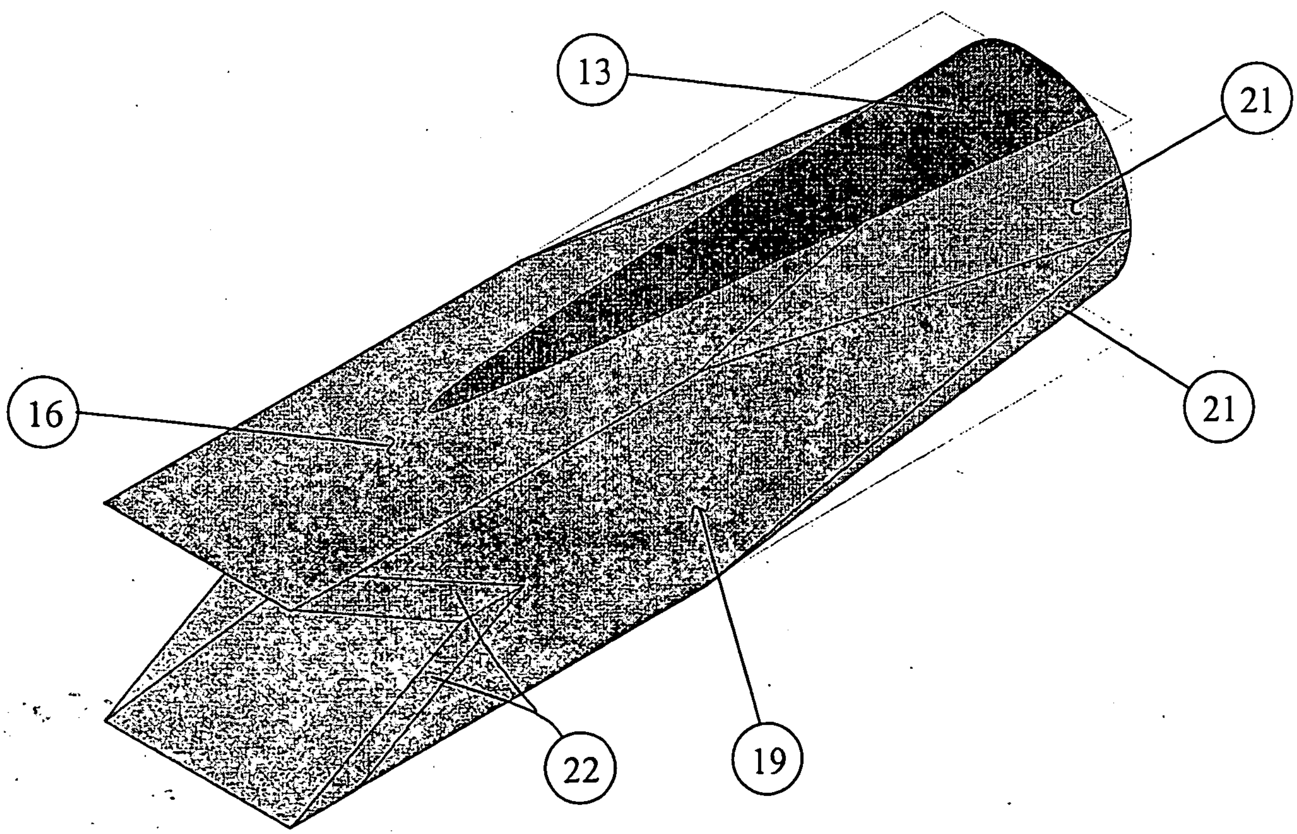
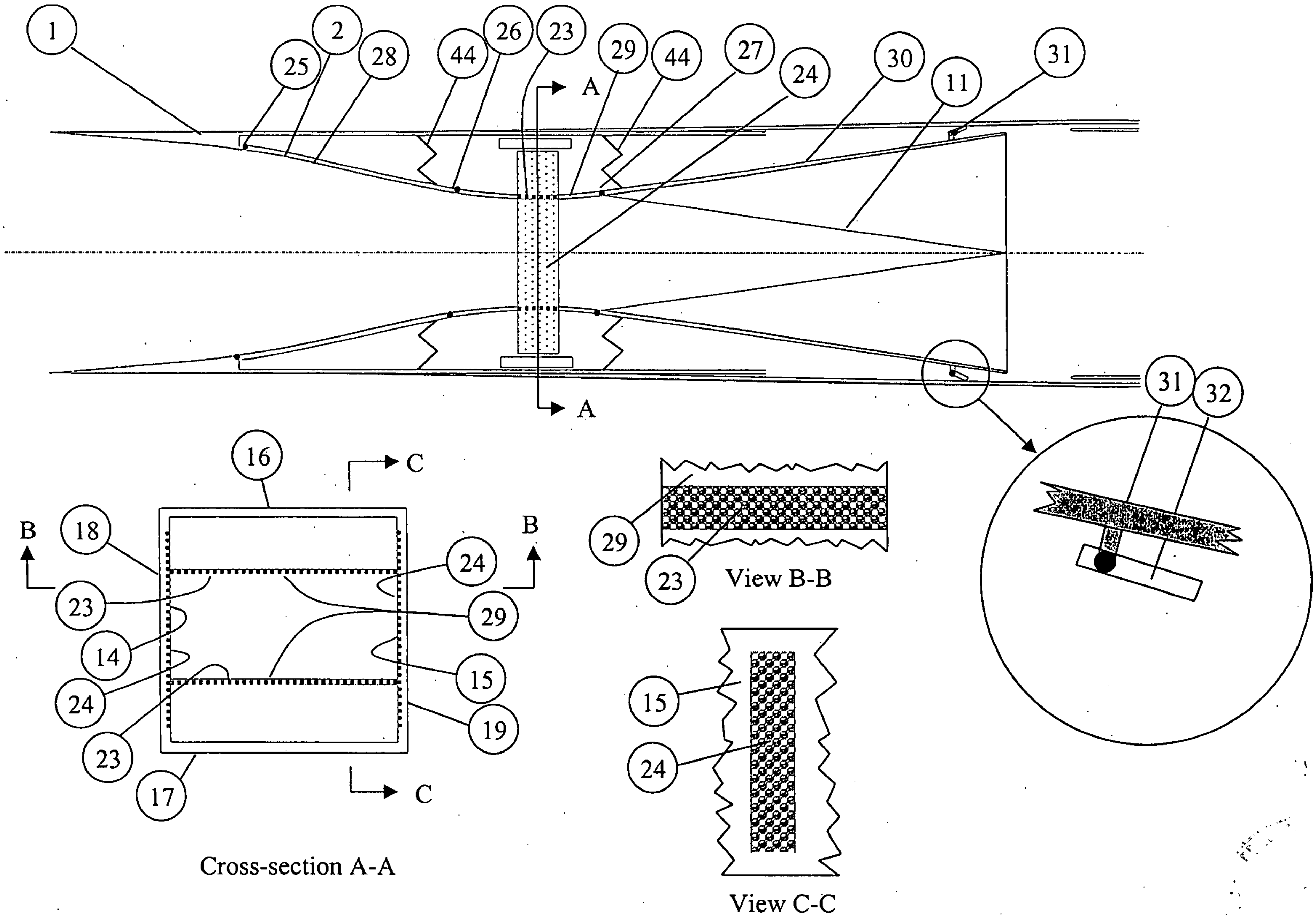


Figure 4


1
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View B-B
15
24
View C-C
Cross-section A-A

Figure 5

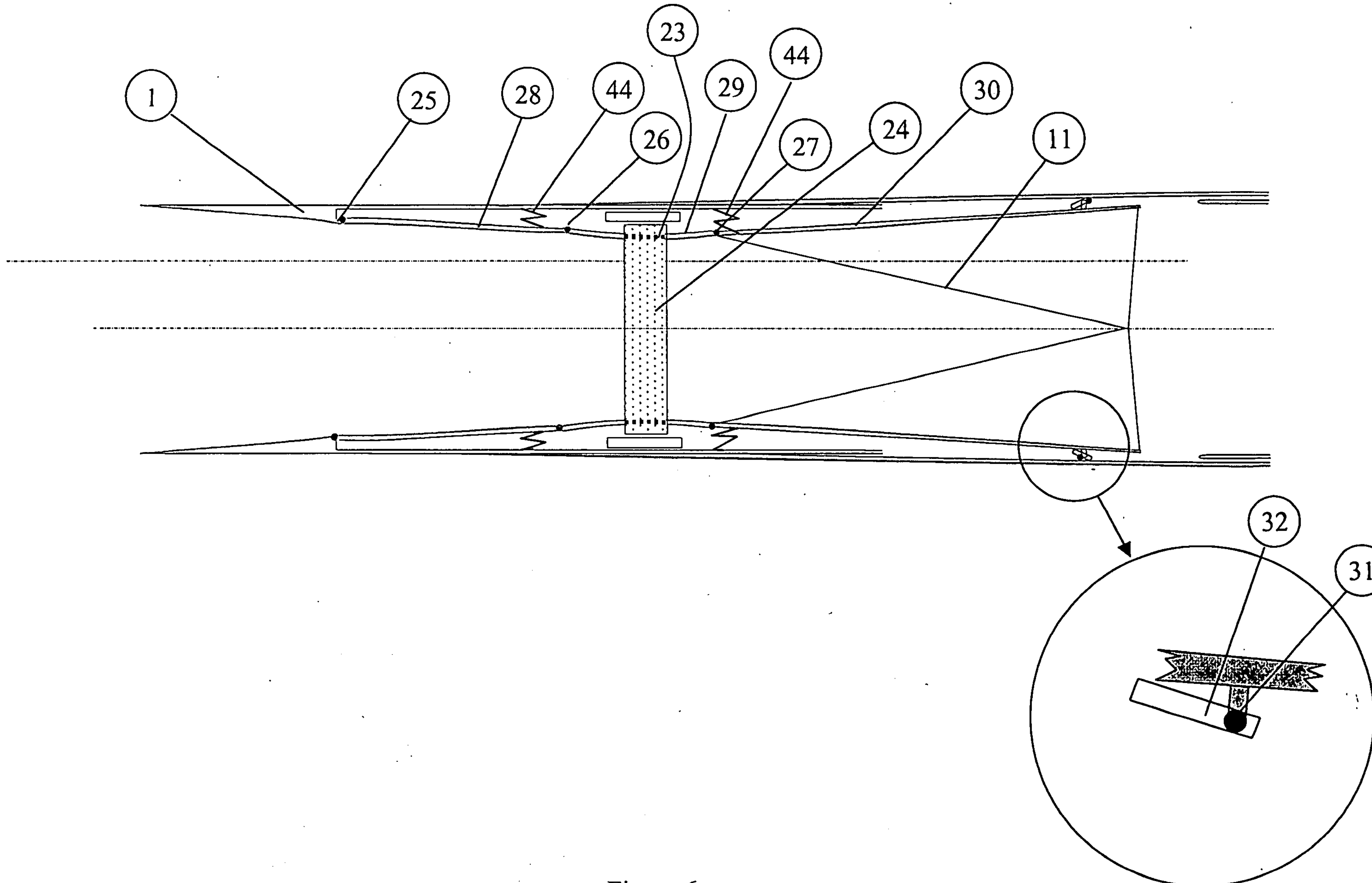
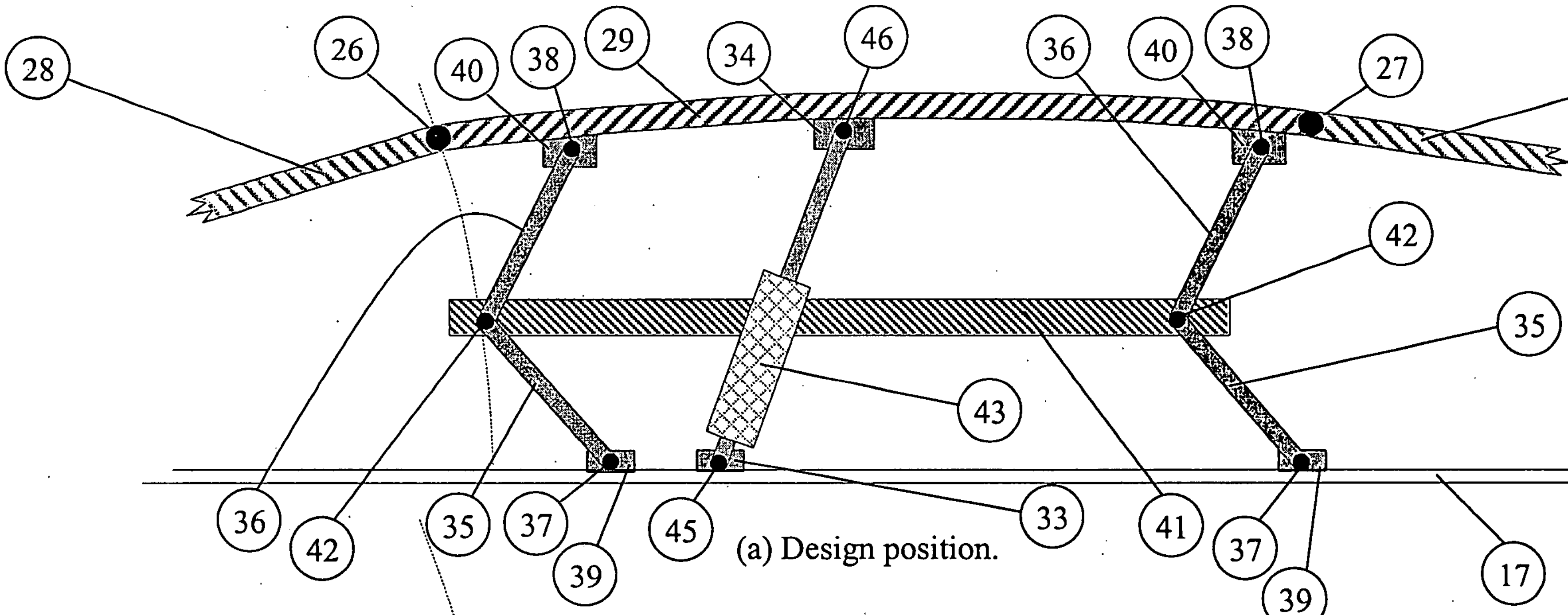
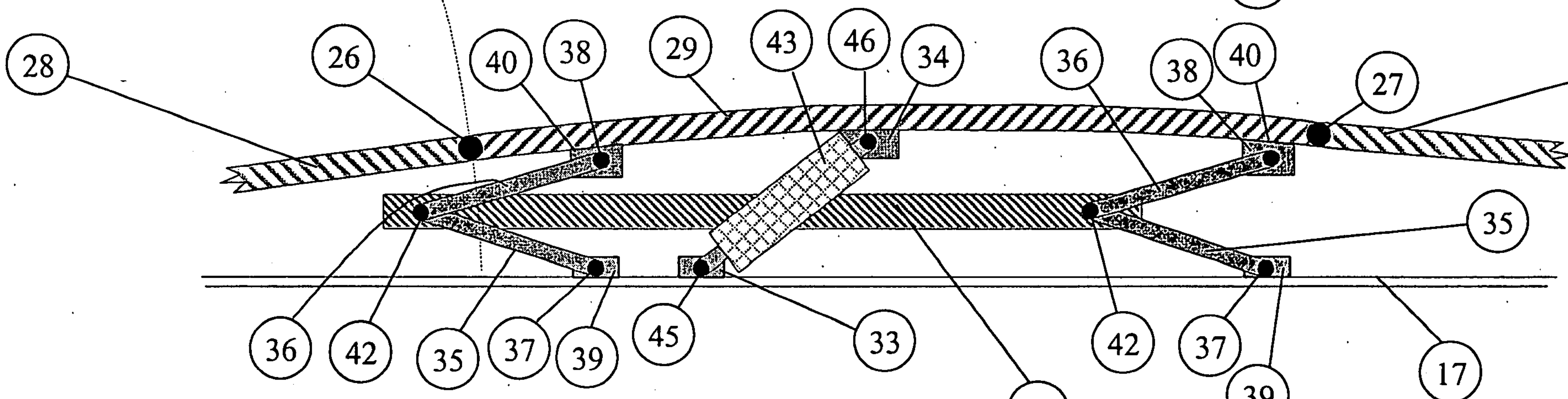


Figure 6



(a) Design position.



(b) Off-design position.

Figure 7

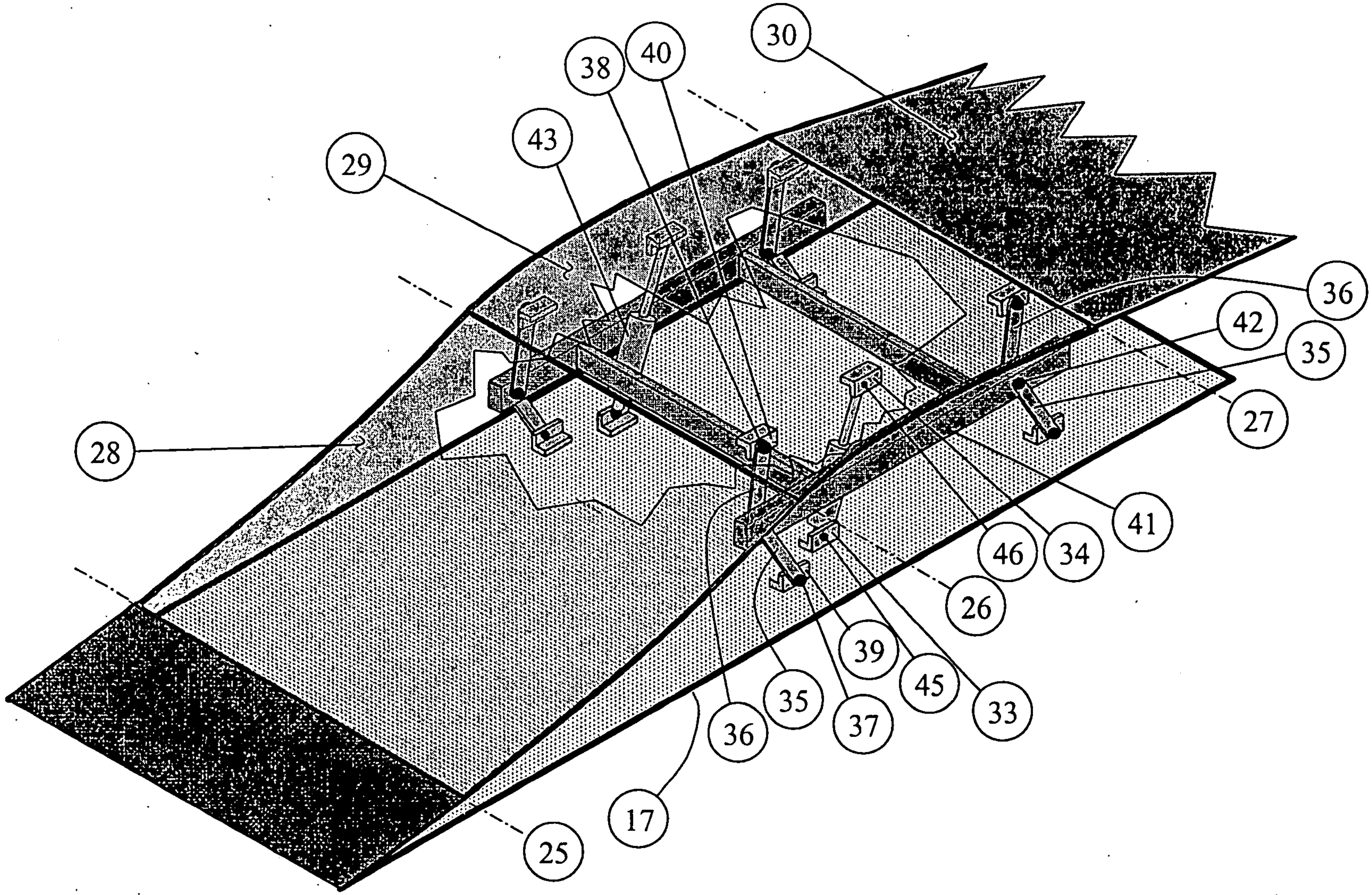


Figure 8

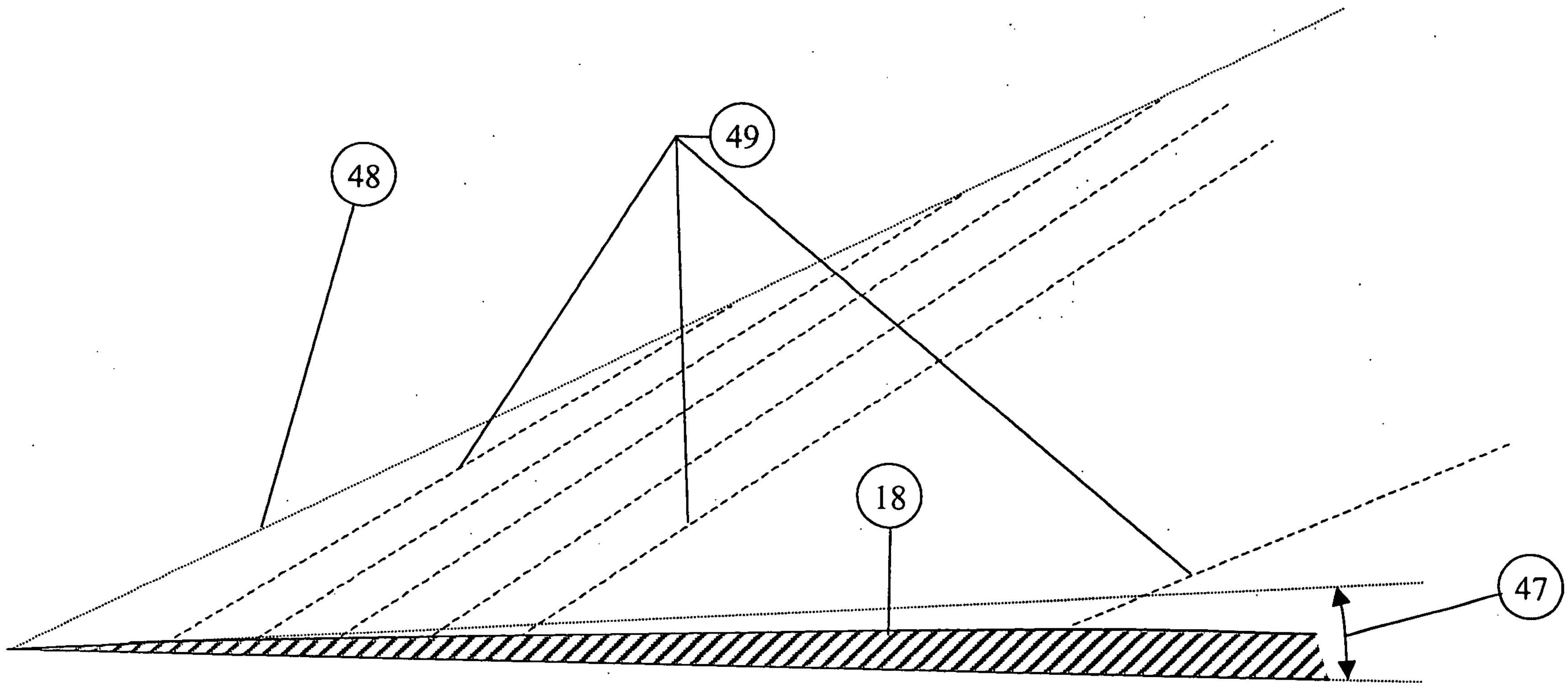


Figure 9

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For: **LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT**
CHG Ref.: 26272/04003

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	26272/04003
First Inventor	Bobby W. Sanders
Title	LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT
Express Mail Label No.	EL084647715US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)
   (Submit an original and a duplicate for fee processing)
2. ☒ Applicant claims small entity status. See 37 CFR 1.27.
3. ☒ Specification *[Total Pages* 22 *]*
   (preferred arrangement set forth below)
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstracts
4. ☒ Drawing(s) (35 U. 113) *[Total Pages* 14 *]*
5. Oath or Declaration *[Total Pages* 3 *]*
   a. ☒ Not executed (original or copy)
   b. ☐ Copy from a prior application (37 CFR 1.63 (d))
   (for continuation/divisional with Box 18 completed)
      i. ☐ DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b)
6. ☒ Application Data Sheet. See 37 CFR 1.76

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7. ☐ CD-ROM or CD-R in duplicate, large table or Computer Program *(Appendix)*
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ACCOMPANYING APPLICATION PARTS

9. ☐ Assignment Papers (cover sheet & document(s))
10. ☐ 37 CFR 3.73(b) Statement *(when there is an assignee)* ☐ Power of Attorney
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12. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
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17. ☒ Other: Verified Statement Claiming Small Entity to follow

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Name (Print/Type)	James A. Rich	*Registration No. (Attorney/Agent)*	25,519
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UTILITY PATENT APPLICATION TRANSMITTAL

Attorney Docket No.	26272/04003
First Inventor or Application Identifier	Bobby W. Sanders
Title	LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT
Express Mail Label No.	EL084647715US

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FEE TRANSMITTAL for FY 2001

Patent fees are subject to annual revision

TOTAL AMOUNT OF PAYMENT	($)355.00

Complete if Known	
Application Number	
Filing Date	September 26, 2001
First Named Inventor	Bobby W. Sanders
Examiner Name	
Group Art Unit	
Attorney Docket No.	26272/4003

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107	490	207	245	Plant filing fee	
108	710	208	355	Reissue filing fee	
114	150	214	75	Provisional filing fee	
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Independent Claims		- 3** =	x	=
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103	18	203	9	Claims in excess of 20
102	80	202	40	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	80	209	40	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

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127	50	227	25	Surcharge - late provisional filing fee or cover sheet	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for *ex parte* reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	390	216	195	Extension for reply within second month	
117	890	217	445	Extension for reply within third month	
118	1,390	218	695	Extension for reply within fourth month	
128	1,890	228	945	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,240	241	620	Petition to revive - unintentional	
142	1,240	242	620	Utility issue fee (or reissue)	
143	440	243	220	Design issue fee	
144	600	244	300	Plant issue fee	
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123	130	123	130	Petitions related to provisional applications	
126	180	126	180	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	710	246	355	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	710	249	355	For each additional invention to be examined (37 CFR § 1.129(b))	
179	710	279	355	Request for Continued Examination (RCE)	
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Citizenship Country:: USA

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Fax One:: 216-241-0816

APPLICATION INFORMATION

Title Line One:: LOW SONIC BOOM INLET FOR SUPE
Title Line Two:: RSONIC AIRCRAFT
Total Drawing Sheets:: 14
Formal Drawings?:: No
Application Type:: Utility
Docket Number:: 26272/04003
Secrecy Order in Parent Appl.?:: No

Source:: PrintEFS Version 1.0.1

LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT

Field of the Invention

This invention relates to air intakes for flight vehicles and, more particularly, to air intakes for aircraft that are designed to fly at supersonic speeds.

Background of the Invention

Inlets for propulsion systems for high speed supersonic aircraft are designed to efficiently decelerate the approaching high-speed airflow to velocities that are compatible with efficient airbreathing engine operation and to provide optimum matching of inlet airflow supply to engine airflow requirements. Entrance airflow velocities to existing air-breathing engines must be subsonic; therefore, it is necessary to decelerate the airflow speed during supersonic flight. The airflow velocities are slowed from supersonic speeds (above the speed of sound) to engine entrance Mach numbers that are subsonic (below the speed of sound).

In aircraft propulsion systems having supersonic inlets, it is essential that the inlet decelerate the airflow in a manner that minimizes the pressure losses, cowl and additive drag, and flow distortion at the engine entrance. For supersonic inlets, efficient deceleration of the supersonic velocities is accomplished by a series of weak shock waves and/or isentropic compression, in which the speed is progressively slowed to an inlet throat Mach number of about 1.30. A terminal shock wave located near the inlet throat slows the airflow from supersonic speeds (above the speed of sound) to subsonic speeds (below the speed of sound). This terminal shock wave typically changes a Mach 1.3 flow condition to a high subsonic flow level. Downstream of the terminal shock, the speed of the airflow is

additionally slowed in the subsonic diffuser of the inlet by a smooth transitioning of the flow duct from a smaller throat area to the larger area at the engine entrance.

Mixed-compression inlets, in which some of the supersonic compression or deceleration in velocity is accomplished external to the duct and some of the compression is accomplished internally, have commonly been proposed for supersonic aircraft that cruise at Mach numbers higher than 2.0. Any inlet that accomplishes some of its compression internally is subject to an undesirable phenomenon known as inlet unstart. Inlet unstart is characterized by an expulsion of the inlet terminal shock from the desirable location at the inlet throat station to a position ahead of the inlet cowling with an associated large increase in drag and large thrust loss. Unstart may also affect the aerodynamics of the aircraft.

Sonic boom is another factor that must be taken into account in the design of inlets of supersonic aircraft. Since economically viable supersonic commercial aircraft must be able to operate supersonically over land, the inlet should contribute minimally to the sonic boom signature of the aircraft. Therefore, the technical challenge for the designer of inlets for modern commercial aircraft is to provide a high performance configuration that provides large operability margins (terminal shock stability to reduce the probability of inlet unstart), and to also identify a design that offers a reduction in the overall sonic boom signature of the aircraft. Mixed-compression inlets can efficiently decelerate the airflow while providing large operability margins. However, the external compression, which is provided by a centerbody or cowl surface, radiates shock waves outward that contribute to the aircraft's sonic boom signature. These designs also have leading edges that include

an external surface at an angle to the local airflow. Oblique shock waves are generated by these surfaces, contributing to the aircraft's overall sonic boom problem. Over-land operation of commercial supersonic aircraft requires that the sonic boom signature from the aircraft be reduced to acceptable levels. In order to achieve the required acceptable boom levels, sonic boom contributions from each component on the aircraft must be reduced to the lowest possible level.

All-internal compression inlets are desirable from a sonic boom reduction standpoint, because they may be designed with no oblique shock waves generated by an external compression system that would contribute to sonic boom signature. However, attempts to design these inlets have been generally unsuccessful, primarily due to large amounts of bleed required for inlet starting and started operation. Since these designs typically utilized fixed geometry, large amounts of bleed were necessary to provide the effective flow area ratio from the inlet entrance to inlet throat to allow the inlet to start (establish a supersonic flow field from the inlet entrance to the inlet throat). Large amounts of bleed were also necessary during normal operation because these inlets did not incorporated a stability system. This trend is typical of inlets that do not incorporate a stability system. Adequate inlet stability margins for inlet operation prior to unstart can only be provided by the fixed geometry bleed systems by prohibitively bleeding large amounts of bleed airflow during normal operation. The development of a low sonic boom aircraft therefore requires an innovation in supersonic inlet design.

Summary of the Invention

The inlets disclosed and claimed herein provide high performance, large operability margins, i.e. terminal shock stability that reduces the probability of inlet unstart, and contribute little or nothing to the overall sonic boom signature of the aircraft. The characteristics of these inlets include very high internal area contraction or compression and very low external surface angles. The design concept of this invention is a very high to all internal compression inlet, in which all shocks from the internal inlet surfaces are captured and reflected inside the inlet duct (no compression system shocks radiated external to the inlet duct). Additionally, they allow all of the external nacelle surfaces to be completely or very nearly aligned with the external flow (zero external surface angles). These low profile external surfaces do not produce a shock wave that contributes to the sonic boom problem. In this invention, an all-internal compression inlet is combined with a shock stability bleed system. The innovative application of a shock stability bleed system can prevent inlet unstarts caused by both internal and external flow disturbances, and provide large shock stability margins, thereby making the all internal-compression, or near all-internal compression inlets feasible for application to supersonic cruise vehicles.

The inlet shock stability system consists of bleed regions that duct bleed airflows to variable area exits. The stability system incorporates either passive or active exit area controls. This system prevents inlet unstarts by removing airflow through a large open throat bleed region to compensate for reductions in diffuser (engine) corrected airflow demand. Because the stability bleed is not removed until the inlet terminal shock moves upstream over the bleed region, the necessary normal shock

operability margin is provided without compromising inlet performance (total pressure recovery, and distortion) and without requiring prohibitive amounts of performance bleed during normal inlet operation. Research has demonstrated that the utilization of a variable bleed exit on a large open throat bleed region can provide very large inlet stability margins for both internal and external airflow variations. The appropriate placement of a stability bleed system in the throat of an all internal-compression inlet makes the design of such a configuration feasible.

This all internal-compression inlet concept is designed to provide the high performance and reliability required for a highly efficient supersonic aircraft and minimally contribute to sonic boom signature. The unique feature of the proposed design is the utilization of an all-internal compression scheme combined with a shock stability system. This type of inlet offers the opportunity to consider external surfaces that are substantially aligned with the approaching airflow that will not produce shock waves and the associated sonic boom. For inlets of this type, all of the supersonic compression is generated by the contouring on the internal surface of the cowl since they do not employ a centerbody.

Other features and advantages of this invention will be apparent to those skilled in the art after reading the following detailed description and the accompanying drawings.

Drawings

Figure 1 shows an isometric view of a low sonic boom all internal-compression inlet embodying this invention.

Figure 2 presents a horizontal cross-sectional view of the inlet shown in Figure 1, showing the internal cowl surfaces and

an indication of the inlet aerodynamics.

Figure 3 shows a downstream view of the inlet, i.e. in the direction of airflow through the inlet, rotated 90° from Figure 1 for ease of comparison with Figure 2.

Figure 4 presents a vertical cross-sectional view of the inlet that shows the internal contours on the top and bottom surfaces of the inlet.

Figures 5 through 9 show cross-sectional views of the inlet.

Figures 10 through 10-D, 11 and 11-A present cross-sections of the inlet that show the cowl surfaces in the on-design (supersonic cruise) position and in the most off-design (low-speed) collapsed condition. The design position is presented in figure 10 and the off-design position is shown in Figure 11. Stability bleed regions are also depicted in Figure 10.

Figures 12 through 14 show a mechanical mechanism to provide variable geometry for a two dimensional (i.e. an inlet of rectangular cross-section in which the external surfaces from the leading edges to the inlet throat are composed of flat or contoured plates) supersonic cruise inlet utilizing all internal-compression.

Figure 15 shows an alternate leading edge for the top and bottom surfaces.

Figures 16 through 18 present approaches to adjust the top and bottom sidewalls of an inlet that is sized to meet the airflow demand of an engine with a requirement for a very low entrance Mach number.

Figure 19 presents a configuration similar to the inlet of Figure 1 with the leading edges of the cowl staggered.

Figure 20 presents an alternate bifurcated inlet configuration that utilizes the staggered concept of Figure 19 in a back-to-back arrangement.

Detailed Description

The basic inlet concept is presented in Figures 1 through 14. Figure 1 shows an isometric view of the inlet, referred to generally as 1, and Figures 2 through 4 present cross-sections of the configuration. The isometric sketch in Figure 1 depicts a supersonic inlet 1 in which all the external surfaces are flow-aligned, i.e aligned with the airflow approaching the inlet. The airflow approaching the inlet is substantially parallel to the inlet centerline; therefore, surfaces that are flow-aligned with the freestream airflow are also parallel to the inlet centerline. The initial external cross-sectional shape of the inlet is rectangular and then transitions as indicated by the surfaces 21 to a round nacelle at the downstream end 10. If the propulsion system uses a square or rectangular nozzle, transitioning of the inlet surfaces, as shown by surface 21 in figure 1, to a round nacelle is not required; therefore, the rectangular cross-section would be continued to the end of the nacelle, station 10. This inlet 1 is composed of four surfaces: the sidewalls 55 and 56 and top and bottom surfaces 53 and 52, respectively, of the inlet. As shown in Figure 3 (rotated 90^0 relative to Figure 1 for ease of comparison with Figure 2), these surfaces (55, 56, 52 and 53) provide the internal channel 51 to duct the captured airflow 77 through the inlet to the exit station 10.

Referring to the horizontal cross-sectional view in Figure 2, inlet 1 uses a low-angle (typically about 5^0 or less relative to the incoming airflow) initial compression wedge 3 on the internal cowl compression surface 2, which generates an initial

oblique shock 4, i.e. a shock wave with an angle less than 90^0 to the surface that is radiated out from the leading edge of from any compression surface angle. For example, a 5^0 wedge in a Mach 2.4 airstream generates an oblique shock wave with a 28.73^0 angle to the incoming airflow. This internal cowl compression surface 2 includes the initial low angle wedge 3, an isentropic contour 5, a throat section 6 (minimum cross-sectional area), and a subsonic diffuser 7. Isentropic compression refers to a compression process that is generated by a continuous curvature of the compression surface in which the airflow is progressively compressed or decelerated with no loss in the total pressure of the airstream. Isentropic compression can be approximated by using a series of small angle changes to develop the overall required compression. The isentropic compression contour 5 provides the additional required supersonic compression or deceleration from the initial wedge 3 to the inlet throat section 6.

The isentropic compression flow field is depicted by the Mach waves 8. For example, in a typical supersonic transport installation, operating at supersonic design conditions of about Mach 2.4, the supersonic airflow will have decelerated to about Mach 1.3 when it reaches the throat 6. A normal (terminal) shock 9 at the inlet throat 6 will typically further decelerate the airflow to about Mach 0.8. The subsonic airflow downstream of the terminal shock 9 continues to decelerate in the subsonic diffuser 7 that extends from the inlet throat 6 to the diffuser exit station 10.

The internal inlet duct 51 is rectangular to a location just downstream of the inlet throat 6 and then transitions to a circular cross-section at a station just upstream of the engine location 10. Tangent lines 11 that are created by filleting the

corners are shown. The subsonic diffuser contains a break in the contour that provides an opening 12 to a typical overboard bypass system (not shown). As indicated in the downstream view of the inlet presented in Figure 3, the initial inlet external surfaces are 16, 17, 18, and 19. Figure 2 shows that external surfaces 16 and 17 are at 0^0 (flow aligned).

A downstream view of the inlet configuration is presented in Figure 3. The distance between the internal surfaces 14 and 15 is equal to the engine diameter 61. These internal surfaces are also shown in Figure 4. The top wall 53 is composed of an inner wall 14 and an exterior surface 18. Surface 14 exhibits an initial small compression surface angle to the incoming airflow 77 that is captured by the inlet. This small internal angle is necessary because the external angle for surface 18 is about 0^0. This small internal compression angle for surface 14 results in a weak shock wave 54. Proceeding downstream from the initial wedge, surface 14 then transitions to an axial direction with an expansion of the flow field. This expansion is represented by an initial expansion wave 64 and a final expansion wave 65. This internal compression - expansion created by surface 14 and by the identical opposite surface 15 should have very little effect on the overall inlet compression process. The airflow conditions approaching the inlet throat terminal shock 9 should mainly be the result of the compression system created by the cowl surface 2 as shown in Figure 2.

Figure 5 shows the locations of several cross-sections (A-A to D-D) on the inlet 1. Cross-sectional views for these cross-sections are presented in Figures 6 through 9. Again as for Figure 3, note that the cross-sections are rotated for ease of comparison with Figures 2 and 5. Cross-section A-A is shown in Figure 6. In Figure 6, both the internal duct (composed of

surfaces 2, 14 and 15) and the external shape (composed of surfaces 16, 19, 17, and 18) are rectangular. The shape is similar for Figure 7 (cross-section B-B, Figure 5) except the distance between the cowl surfaces 2 show the restriction of the duct area in the throat (minimum area) of the inlet. Figure 8 shows the transitioning of the inlet to circular, both internally and externally. The external surfaces are transitioned by the circular arcs 21, and the internal surfaces are transitioned by the circular arcs 20. Figure 9 shows a cross-section near the exit of the inlet in which both internal and external contours are circular.

This inlet utilizes a significant amount of isentropic compression. The benefits of isentropic compression and a throat Mach number of about 1.3 will result in excellent total pressure recovery. In addition, the overall reduction in performance due to boundary layer will be lower for an all-internal compression inlet than for of a conventional mixed-compression inlet, since the basic inlet of this disclosure does not employ a centerbody. Inlets must provide a range of mass flows over which they can operate without the occurrence of an inlet unstart. Traditional performance boundary layer bleed systems can provide only a small operability margin. Since this margin is generally not sufficient, additional margin is provided by operating at reduced performance levels. A very high level of performance and an adequate operability margin to prevent inlet unstart can be realized through the utilization of a stability bleed system. This system allows operation of the inlet at the optimum performance condition, and yet provides significant shock stability margins under conditions where an inlet unstart might tend to occur, such as when the terminal shock moves upstream through the throat region of the inlet due

to a transient reduction in engine airflow demand. The inlet stability bleed system compensates for changes in diffuser exit (engine) airflow demand by removing increasing amounts of airflow from the inlet as the terminal shock moves upstream over the open bleed regions that are located in the throat of the inlet. The stability system functions to provide the necessary stability margins to prevent inlet unstart without prohibitive amounts of bleed during normal inlet operation by using variable area exit control valves that limit the amount of bleed flow until increased bleed is required in response to the upstream movement of terminal shock resulting from a transient disturbance in inlet subsonic diffuser airflow.

An inlet throat stability bleed system is shown in Figures 10 through 10-D. Uniformly distributed porous bleed is the preferred method to remove bleed airflow; however, any type of bleed opening can be used. For the preferred configuration, porous bleed surfaces are located in the inlet throat section. Cowl bleed regions 23 are located in cowl section 29, and sidewall bleed regions 24 are located in sidewalls 14 and 15 (see Figures 10-B and 10-C). In the preferred embodiment, the open bleed regions 23 and 24 consist of the inlet surfaces with 0.125-inch holes drilled normal to the surface to obtain 40% open area (40% porosity). The bleed holes are located on 0.1875-inch centers with the holes in adjacent rows staggered to obtain a uniform distributed pattern. The preferred bleed surface would include a surface thickness to hole diameter ratio of 1.0. The sidewall bleed 24 extends beyond the design cowl position so that bleed can be removed during off-design operation. Folding compartment seals 44 are used to direct the inlet bleed from the bleed surfaces (23 or 24) to exit passages and variable-exit area controls, such as active or passive fast-

acting valves (not shown) at the bleed plenum exit, which control the amount of bleed that is removed from the inlet.

Figures 10, 10-D, 11 and 11-A also illustrate one variable cowl geometry system that can provide the necessary variation of the internal surface geometry and well as changing the duct cross-sectional area at the inlet throat. Engine airflow demand varies as the flight vehicle speed changes from takeoff to supersonic cruise; therefore, a variation in the minimum duct area is necessary to accommodate the changes in airflow. For efficient inlet operation, the internal surface geometry must also be changed as the speed of the aircraft changes. This surface variation as the flight vehicle speed changes allows the most optimum compression of the airflow that enters the inlet system. The internal inlet duct must be opened to a large area as illustrated in Figure 11 during takeoff and for low speed flight. As the flight vehicle accelerates to supersonic conditions, the variable geometry system is used to both provide the proper variation in inlet throat area as well as surface geometry. Comparison of the internal duct 51 geometry of Figures 11 and 10 shows the wide changes in the inlet geometry from takeoff to cruise speeds. Three hinge locations 25, 26, and 27 are shown in the Figures; however, the number of hinges may be any number suitable to provide proper cowl geometry at off-design conditions. The variable cowl consists of an upstream section 28 hinged (25) at the upstream station and connected to additional cowl sections 29 and 30 with hinges 26 and 27, with the downstream end of the last section 30 including a guide pin 31 in a groove 32 (detail) to allow the length change for off-design operation, Figure 10. The track 32 for the guide pin 31 is aligned to properly position the downstream end of the last cowl section 30. All cowl sections are hinged to the first cowl

section 28. A sketch of the cowl in the off-design position is presented in Figure 11. Note the change in position of the downstream guide pin 31 between Figures 10 and 11.

Additional details of this variable cowl geometry scheme are presented in Figures 12 through 14. Hydraulic actuators 43 are utilized to collapse the cowl surfaces for off-design operation. These cylinders 43 are pinned 45 to bracket 33 that is attached to the outside surface 16 or 17 at one end and pinned 46 at the other end to bracket 34 that is attached to cowl surface 29. The hydraulic cylinders are attached to a common fluid supply source so that uniform movement is obtained. Two actuators are shown in Figure 14; however, any number could be used that would fit within the space available and effect the desired movement of the cowl surfaces. While the hydraulic actuators provide the actuating power, the actual movement of the second cowl section 29 is controlled by a scissors arrangement that provides parallel positioning of the section for any operating condition of the inlet. Figure 12 shows that this scissors arrangement is comprised of link bars 35 and 36 that are pinned 37 and 38 to brackets 39 and 40 at the outer ends and pinned to frame 41 at pin 42. Frame 41 is also shown in the isometric sketch of Figure 14. The off-design position of the cowl 29 is shown in Figure 13. As indicated in a comparison of the cowl 29 vertical positions between Figures 12 and 13, the inlet throat surface can be actuated to provide a significant increase in duct area for off-design operation. The parallel throat sections 29 at design and off-design positions are shown in Figures 12 and 13.

Figure 1 shows an inlet with all external surfaces flow-aligned. However, this design requires the use of a small amount of compression on the wall of the inlet as shown in

Figure 4. Although small, as discussed for Figure 4, this additional compression does result in some 3D flow in the inlet. The small internal compression wedges on the top and bottom inlet walls of the inlet generate a flow field that has a vertical crossflow component. This crossflow component in the vertical plane of the inlet interacts with the crossflow component that is generated by the compression surfaces in the horizontal plane. This interaction results in a 3D flowfield. This additional compression could be avoided if a configuration as presented in Figure 15 is utilized. This design basically reverses the initial leading edge angle for the top and bottom walls from a wedge angle on the inside surface to an angled wedge 22 on the exterior surface 71. Therefore, the resulting internal surface is flat with no additional compression to create 3D flow effects. While the small angle on the exterior surface will generate a weak shock wave, it should not significantly contribute to the sonic boom signature. Thus, the inlet configuration 81 of Figure 15 offers the significant advantages of the all-internal compression configuration with a small compromise in the external surface sonic boom contribution for optimum internal aerodynamics.

The basic design problem of providing low external surface angles for lower supersonic cruise Mach number inlets is that the ratio of inlet capture area to engine face area gets smaller as the inlet design Mach number decreases, particularly for inlets matched to jet engines that require low entrance Mach numbers. For the Mach 2.4 inlet design that is presented in Figures 1 through 14, sizing of the inlet capture area to supply airflow to the jet engine 61 at an entrance Mach number of about 0.4 provides an inlet 1 in which the angles of the external surfaces 16, 17, 18 and 19 are 0^0 relative to the approach

airflow 77 as shown in Figures 1 through 14. For this flow-aligned external-surface design, the external cross-sectional area of the inlet at the engine face station 10 was increased by an amount necessary to provide a sufficient annular airflow passage between the outside of a jet engine 61 and the outer nacelle 62 (Figure 2) for cooling airflow around the exterior of the engine. The inlet of Figures 1 though 15 represent a design that has a minimum contribution to the sonic boom of a supersonic cruise aircraft.

If an engine is selected for a Mach 2.4 inlet that requires an entrance Mach number less than about 0.4, all of the external surfaces cannot be aligned with the approach airflow. For low Mach number at the entrance to the engine, the engine area relative to the inlet entrance area will be larger, and a slight external angle on the top 16 and bottom 17 surfaces will result. Two transition schemes for the additional bulge are shown in Figures 16 through 18. Since the largest cross-sectional area is at the inlet exit 10 (engine entrance), the largest bulge on the external surface will be at this location. To obtain a low boom design for this inlet/engine combination, the external surface of the inlet is transitioned to the larger engine face area over a large distance on the nacelle upstream of the bulge, allowing a very small external angle and minimizing the resulting shock strength. The transitioning may have a circular arc shape 13 as shown in Figure 16. As shown in Figures 17 and 18, the transitioning to the larger engine may extend along the entire surface 72 as a curved flat surface 73 to the engine face 10. In Figure 18, only the surface contour 73 is shown. In either case, the low angled contouring of the transitioning surface (13 or 73) would have little to no contribution to the sonic boom signature of the aircraft.

Several alternate configurations can be derived from the inlet design that is shown in Figures 1 through 18 without departing from the basic design approach to identify a very low boom inlet configuration. Two such inlet configurations are shown in Figures 19 and 20. A staggered inlet configuration 90 is presented in Figure 19. Only the supersonic diffuser of the inlet, from the leading edges 67 and 68 to the inlet throat station 97, is shown in Figure 19. The subsonic diffuser for this configuration would be similar to the one 7 shown in Figure 2. This inlet 90 is basically identical to the inlet 1 of Figure 1 except the leading edges 67 and 68 have been staggered to begin at different axial stations. This design offers the same performance and operability, would incorporate stability and variable geometry systems, and would have no external shock waves (no sonic boom) during operation at design conditions. Staggering of the leading edges offers some advantage for spilling airflow at off-design conditions. For the inlet 1 configuration of Figure 2, in which the leading edges of the cowls 16,and 17 begin at the same axial position, airflow cannot be spilled around the cowling during off-design flight speed conditions until the inlet unstarts. Upon unstart, airflow can spill around the cowling after it passes through a strong normal or bow shock that is located ahead of the inlet. Spilling airflow behind a strong normal shock has higher drag than supersonic spillage (spilling behind a supersonic oblique shock). Staggering of cowl lips 67 and 68 of inlet 90 (Figure 19) offers an unstarted inlet in which the normal shock is located ahead of lip 67 and an oblique shock is generated by lip 68. This oblique-normal shock combination offers more efficient spillage of the airflow due to the reduction of the velocity through the oblique shock prior to further deceleration through the normal shock.

An alternate inlet 50 developed by using the same design approach as for the inlets 1 and 90 of Figures 2 and 19 is shown in Figure 20. The inlet 50 of Figure 20 employs the staggered leading edge inlet design of Figure 19 in a back-to-back arrangement to create a bifurcated configuration with a variable geometry centerbody and flow aligned external surfaces 76 and 78. Inlet 50 of Figure 20 is derived by placing surfaces 96 of two inlet 90 from Figure 19 together in such a way that a back-to-back bifurcated inlet configuration is obtained. The internal duct rectangular cross-section at the throat of each of these inlets would be transitioned to a semi-circle at the exit 79 of the inlet to jointly form a round entrance for a single engine. The large amount of staggering of the leading edges, leading edge 85 to 86 and leading edge 85 to 87, for this configuration would provide nearly the same off-design spillage characteristics as a more conventional mixed-compression inlet design. This inlet design 50 has all shock waves 62 and 88 internal to the duct and all external surfaces 76 and 78 of cowls 74 and 75 are flow aligned; therefore, this design, unlike conventional designs, will not contribute to the sonic boom signature of the aircraft at design operating conditions.

The inlets defined in Figures 1 through 20 represent a new approach to inlet design. This invention offers inlet design options that can lead to new, more efficient, safer, and more environmentally friendly aircraft. This inlet concept may offer integration options that were not possible with more traditional inlets. This design approach can provide an inlet configuration that will provide enabling technology for a quiet (low sonic boom), efficient, supersonic cruise aircraft.

While 2-dimensional inlet configurations have been described in Figures 1 through 20, it will be evident to those

skilled in the art that the concept may be extended to the design of axisymmetric inlets with similar attributes and benefits.

It is understood that the invention is not limited to the specific embodiments herein illustrated and described, but may be used in other ways without departing from its spirit. Other embodiments of the internal compression inlet described herein that suggest themselves to those skilled in the art are intended to be covered by the claims of this disclosure which are as follows:

We claim:

1. A supersonic air inlet, wherein substantially all of the air compression takes place within said inlet, incorporating a shock stability bleed system, and comprising external surfaces that are substantially aligned with the airflow approaching the inlet in order to minimally contribute to the sonic boom signature of an aircraft.

2. An inlet according to claim 1 further comprising a stability bleed system that is comprised of bleed regions on the interior surfaces of the inlet exiting into bleed plenums with fixed or variable-exit area control valves, that provides the inlet with the necessary tolerance to changes in engine mass-flow demand or external disturbances (changes in incoming flow angularity or speed), and which prevents inlet unstart under such adverse conditions.

3. An inlet according to claim 2, further comprising variable cowl surface geometry to provide the variation in surface geometry and throat area necessary for optimum inlet performance and meeting the propulsion system's off-design mass-flow demand schedule.

4. An inlet according to claim 3 which is two-dimensional or axisymmetric.

5. An inlet according to claim 4 wherein interior surfaces of said inlet are composed of a series of distinct compression angles, or form a substantially isentropic compression system between said inlet initial angled compression surface and throat of said inlet.

6. An inlet according to claim 5 wherein the downstream exterior inlet surfaces may be maintained as a rectangular cross-section or transitioned to a round nacelle.

7. An inlet according to claim 6 wherein said external surfaces are aligned with the flow of air to the inlet, and interior surfaces at the entrance of the inlet are at an angle of about 2° to 5° to said flow.

8 An inlet according to claim 6 wherein said external surfaces are within about 5° of parallel to the flow of air to the inlet, and interior surfaces at the entrance to the inlet are at angles of about 3° to 10° to said flow.

9. An inlet according to claim 6, wherein external surfaces that are not aligned with the flow consist of a small initial surface angle on the external sidewall and 0° flow aligned internal sidewall surfaces thus eliminating internal sidewall compression and three-dimensional internal flow.

10. A inlet according to claim 1 wherein: substantially all compression shocks are reflected on the internal surfaces; and cowl leading edges are staggered in accordance with off-design Mach number spillage considerations.

11. An inlet according to claim 10 wherein a single bifurcated inlet is derived by joining the exterior surfaces of the longer cowl of two inlets of claim 9 to form a back-to-back arrangement with the duct from the throat of each resulting supersonic diffuser being transitioned to a semicircle at the exit to jointly form a round entrance for a single engine.

Abstract of the Disclosure

All-internal compression inlets for supersonic aircraft, with variable geometry systems and shock stability bleed systems provide high performance, large operability margins, i.e. terminal shock stability that reduces the probability of inlet unstart, and contribute little or nothing to the overall sonic boom signature of the aircraft. These inlets have very high internal area contraction or compression and very low external surface angles. All shocks from the internal inlet surfaces are captured and reflected inside the inlet duct, and all of the external nacelle surfaces are substantially aligned with the external airflow. The inlet shock stability system consists of bleed regions that duct bleed airflows to variable area exits with passive or active exit area controls. This reduces the risk of inlet unstarts by removing airflow through a large open throat bleed region to compensate for reductions in diffuser (engine) corrected airflow demand. Because the stability bleed is not removed until the inlet terminal shock moves upstream over the bleed region, the necessary normal shock operability margin is provided without compromising inlet performance (total pressure recovery, and distortion).

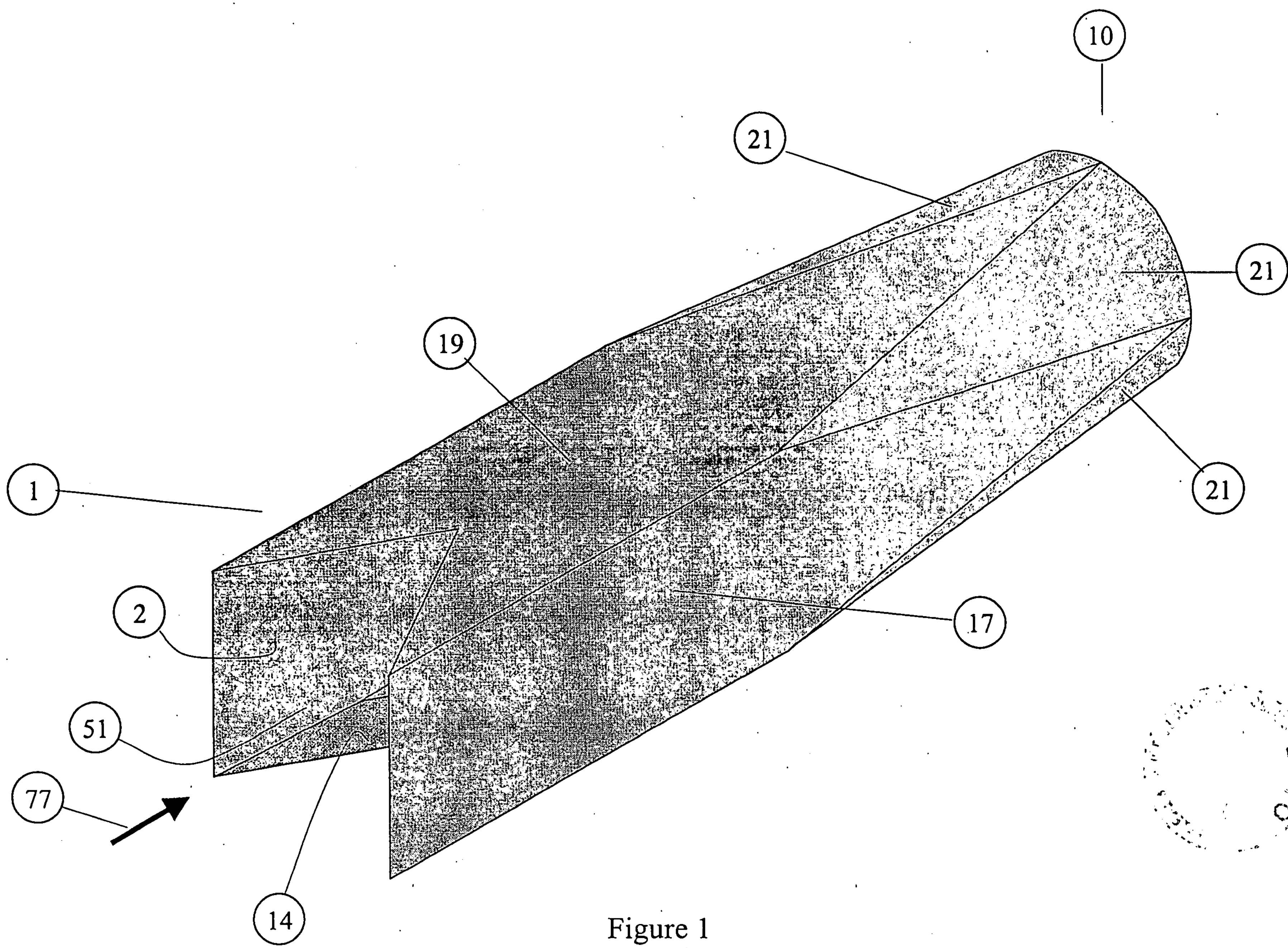

Figure 1

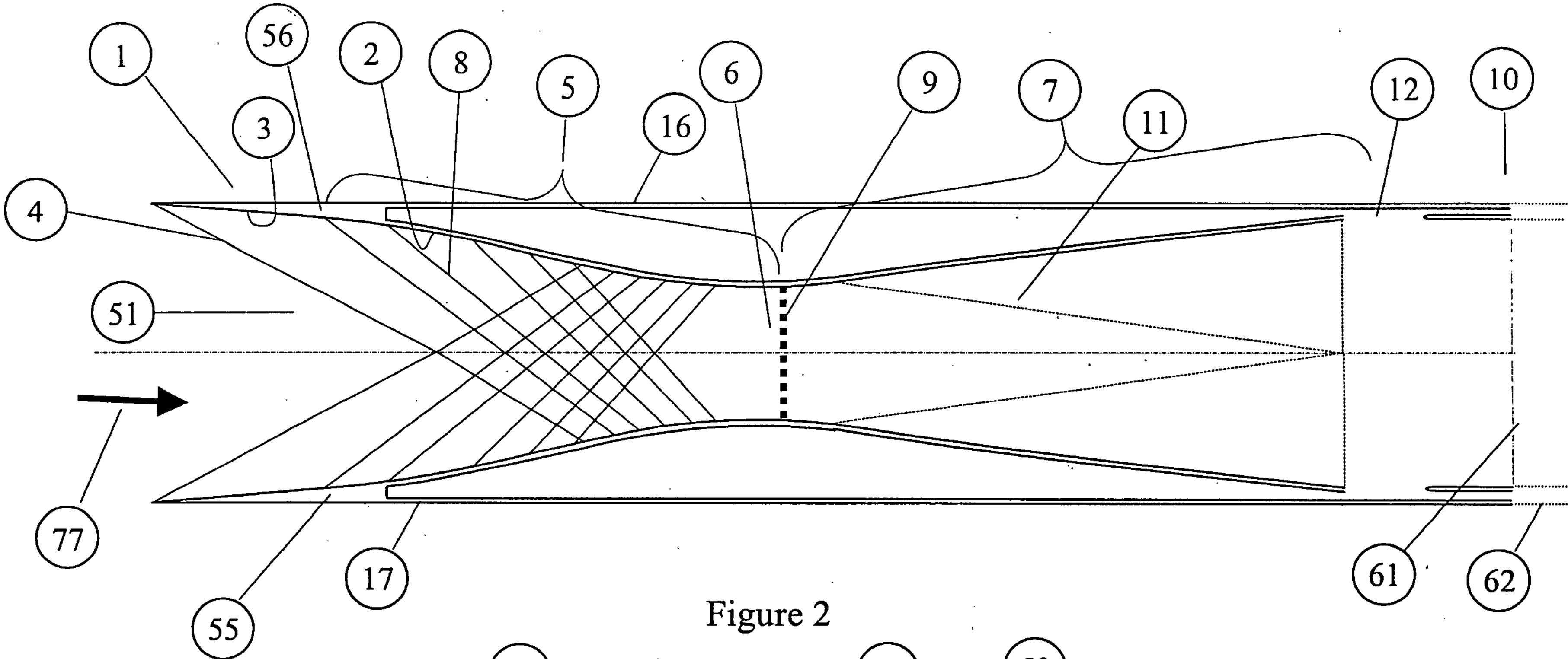

Figure 2

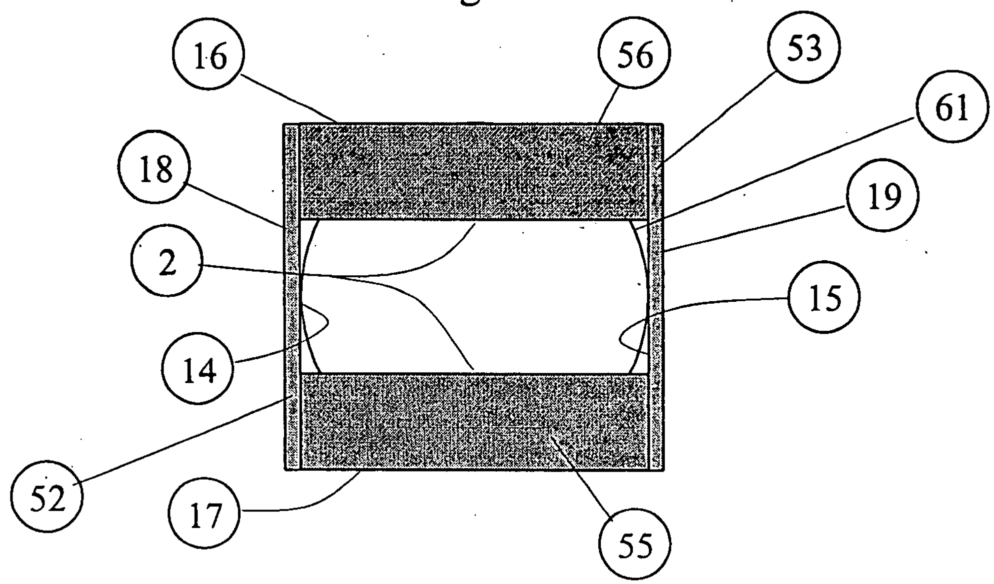

Figure 3

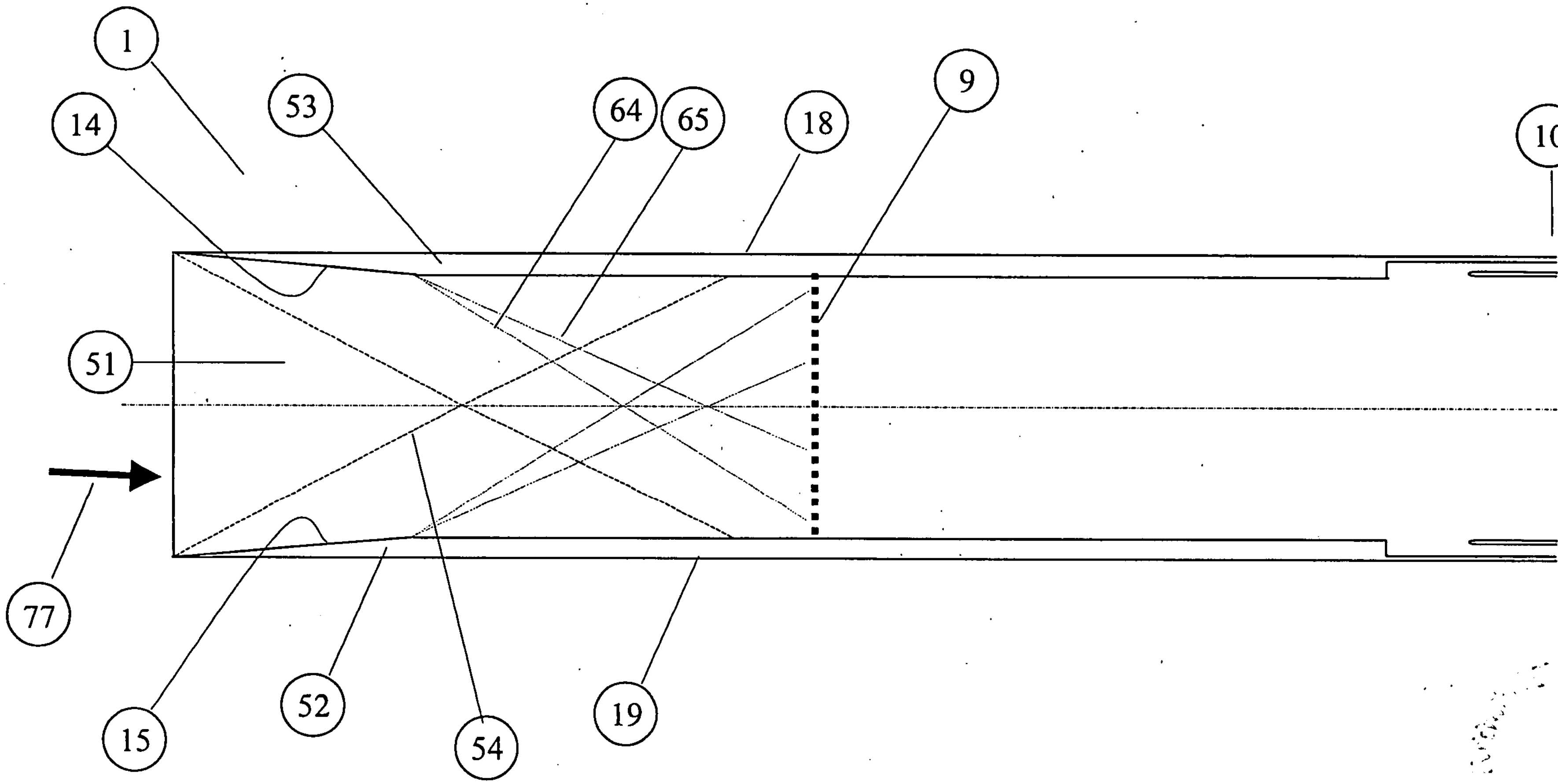

Figure 4

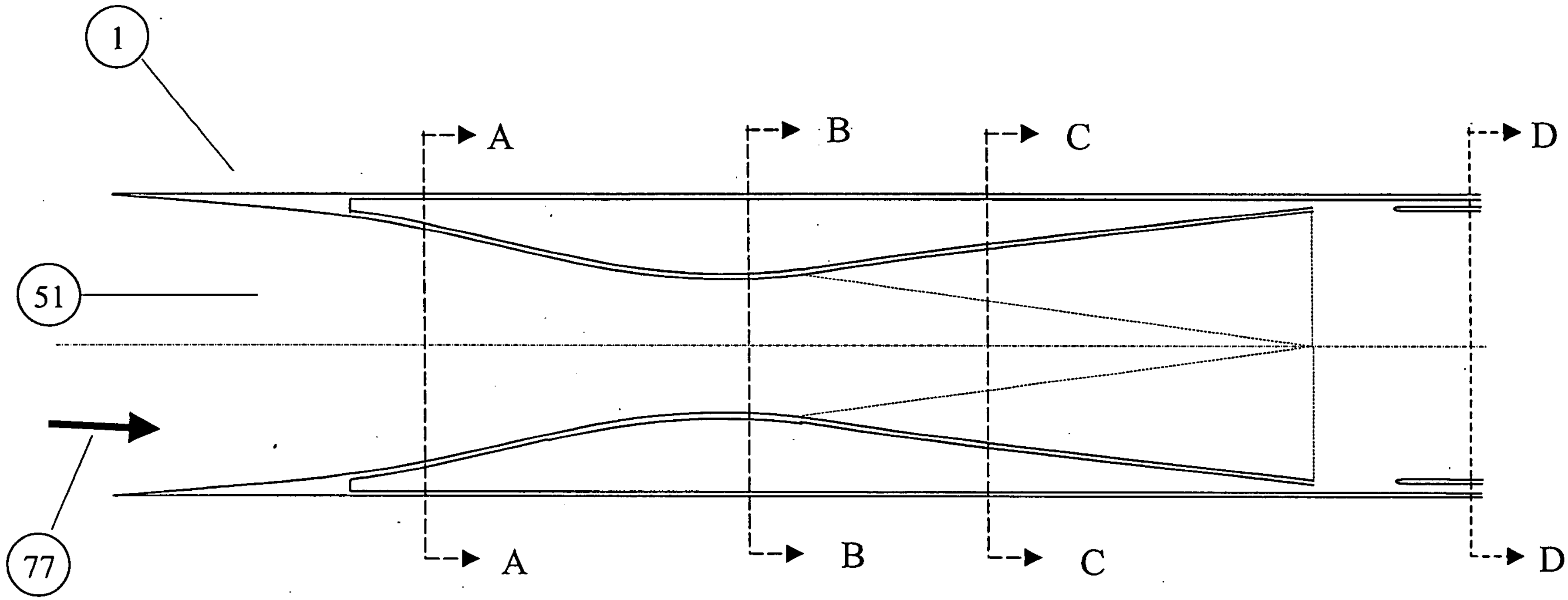

Figure 5

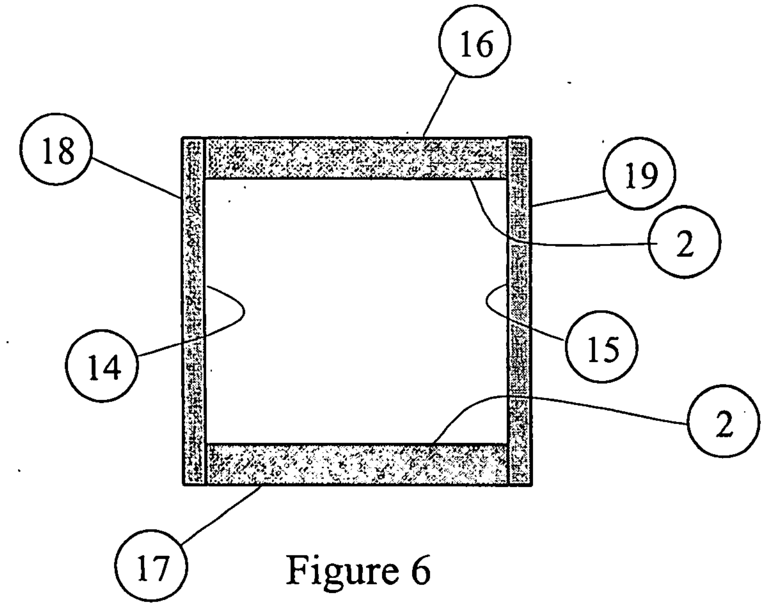

Figure 6

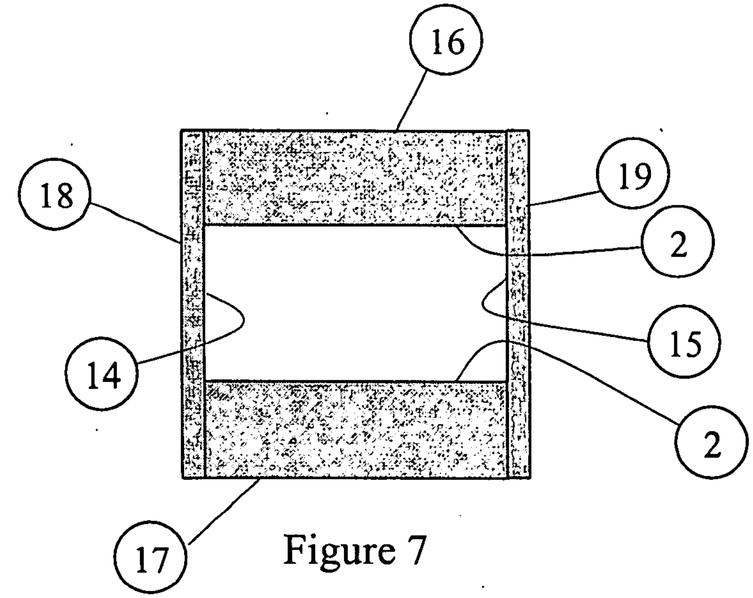

Figure 7

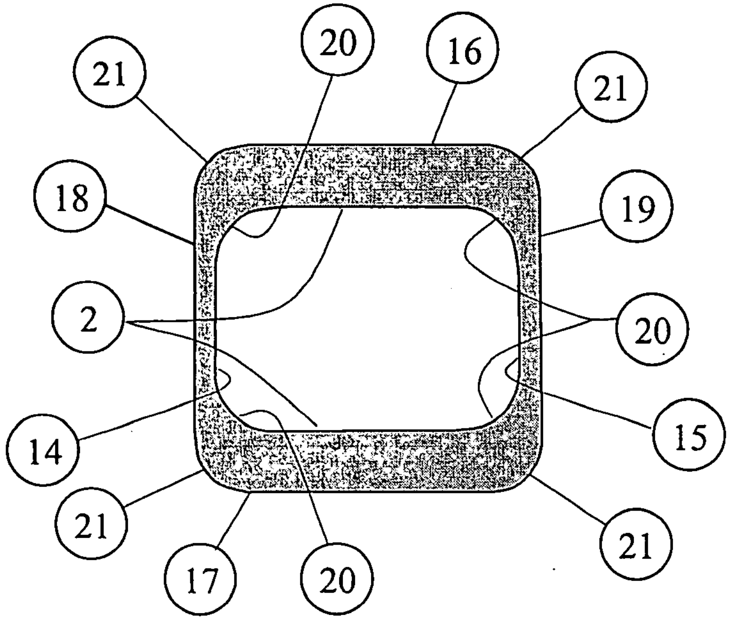

Figure 8

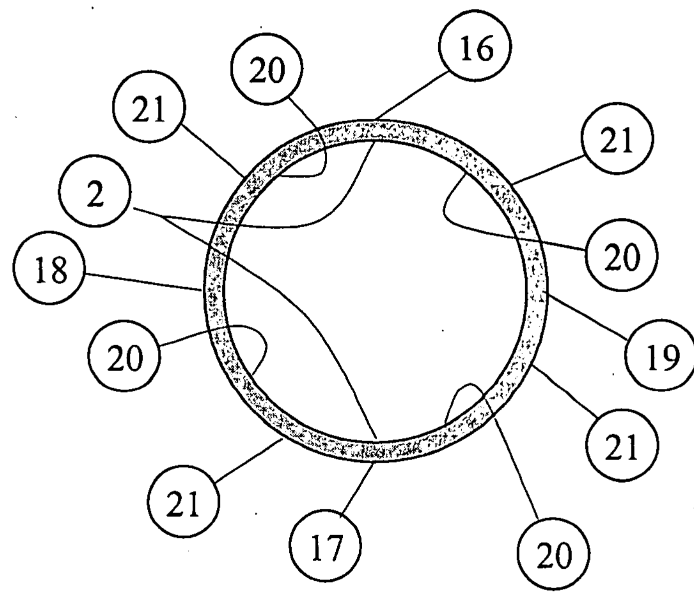

Figure 9

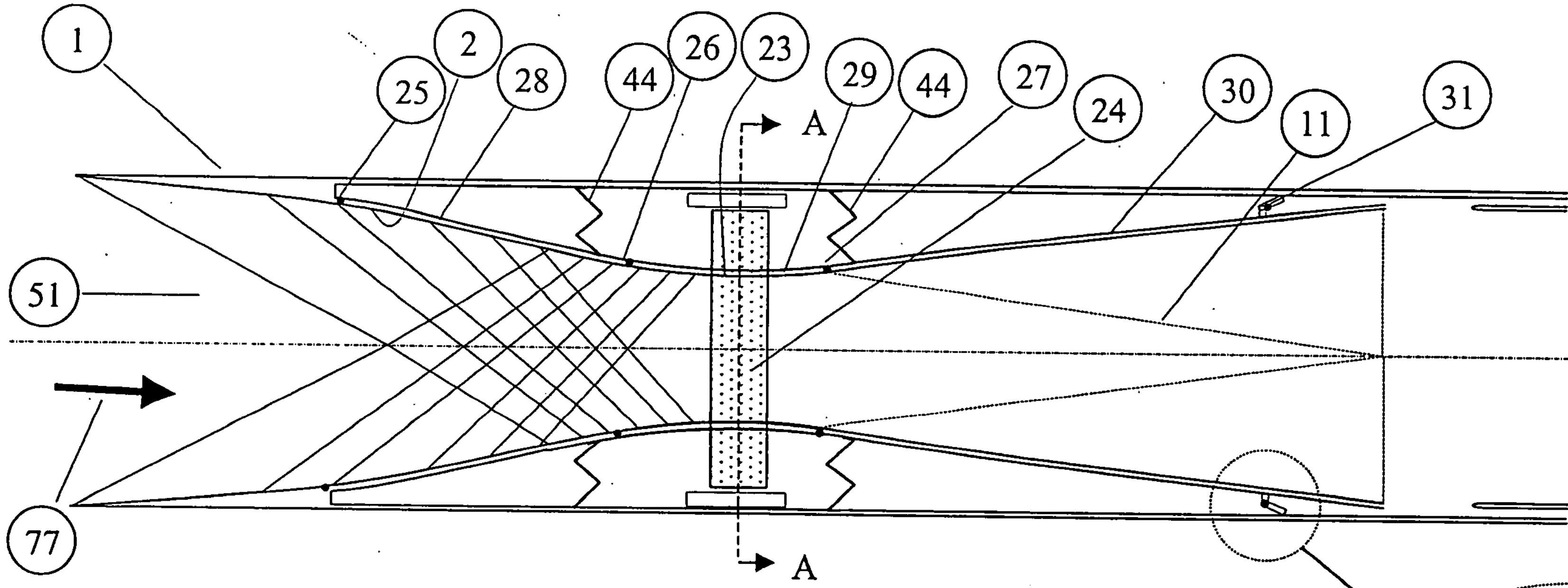

Figure 10

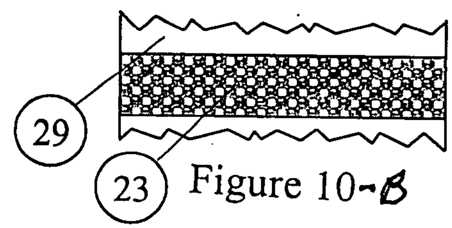

Figure 10-B

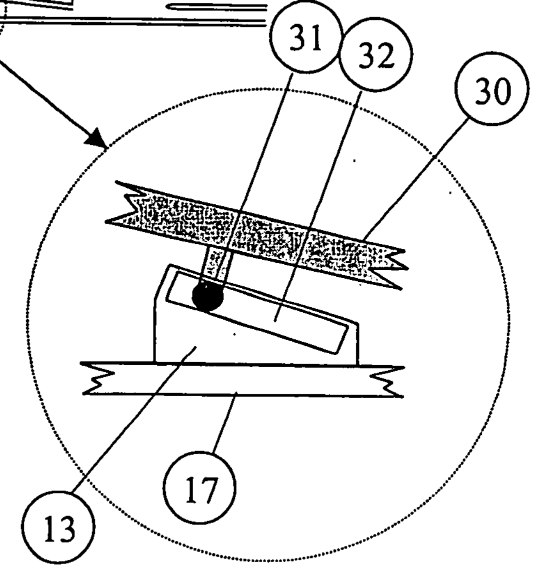

Figure 10-D

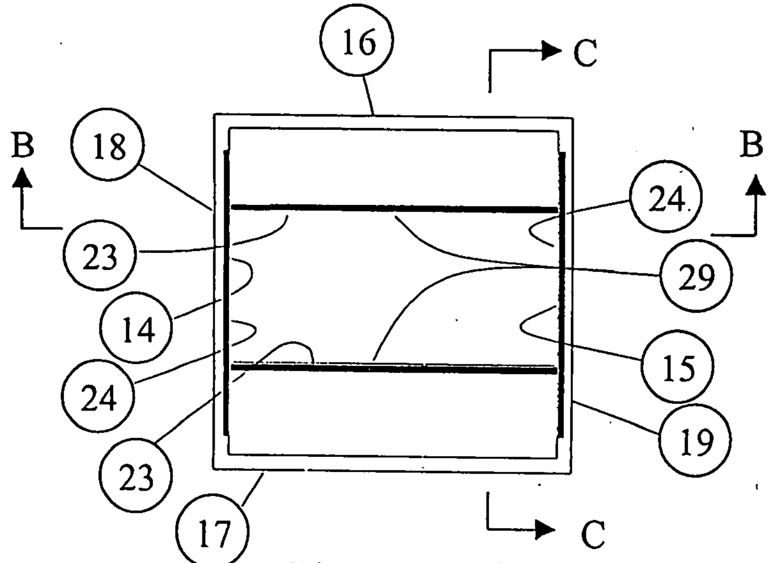

Figure 10-A

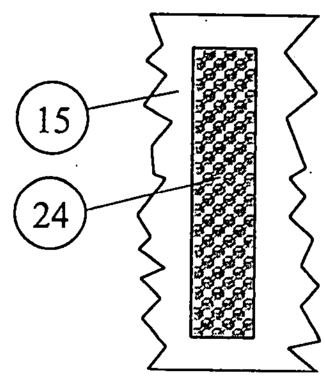

Figure 10-C

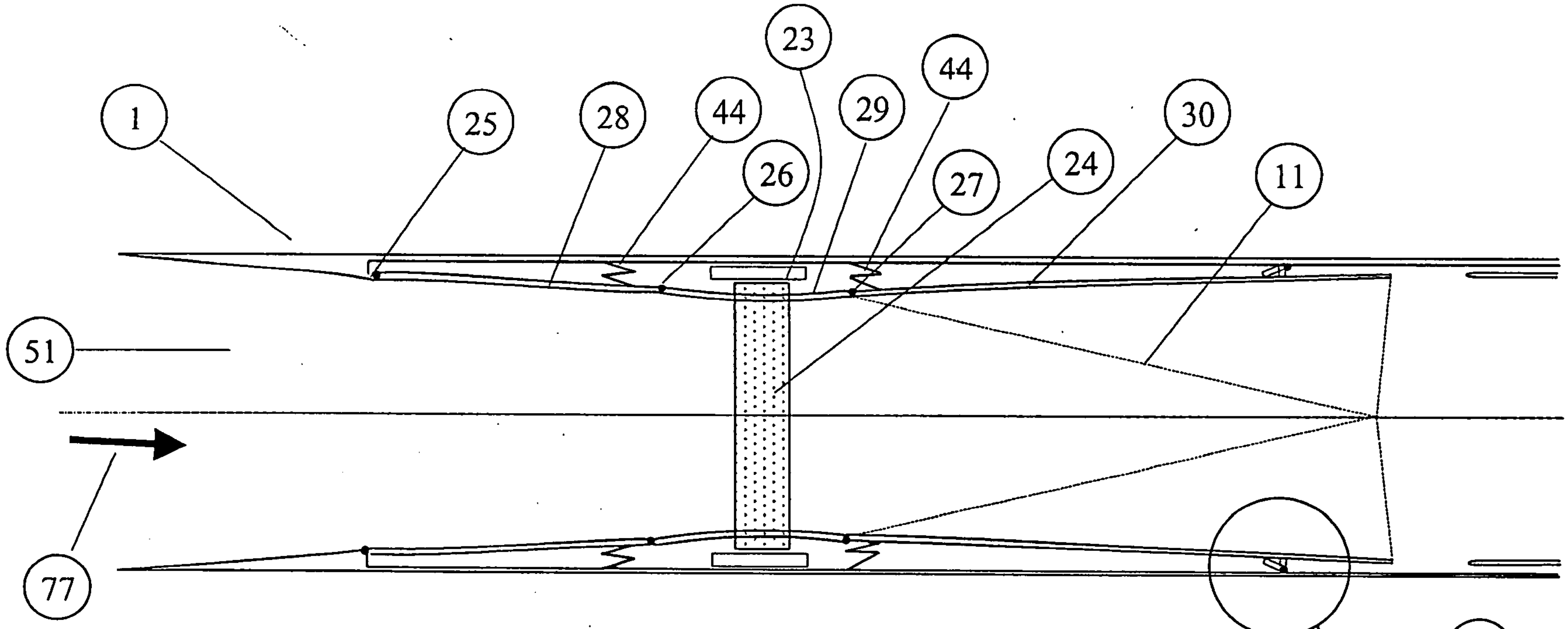

Figure 11

~~Figure 11~~

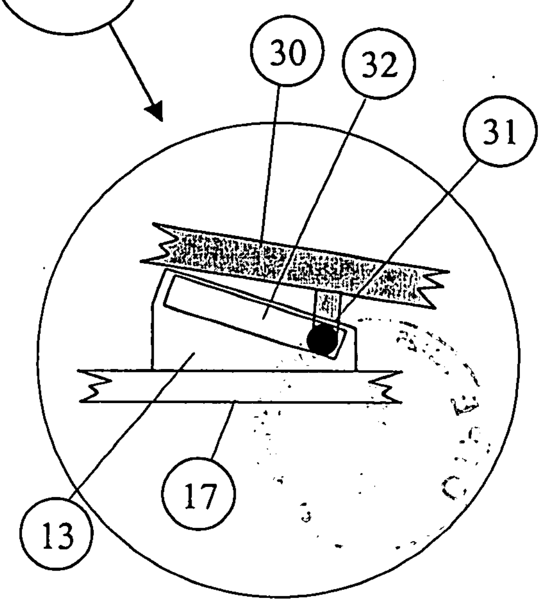

Figure 11-A

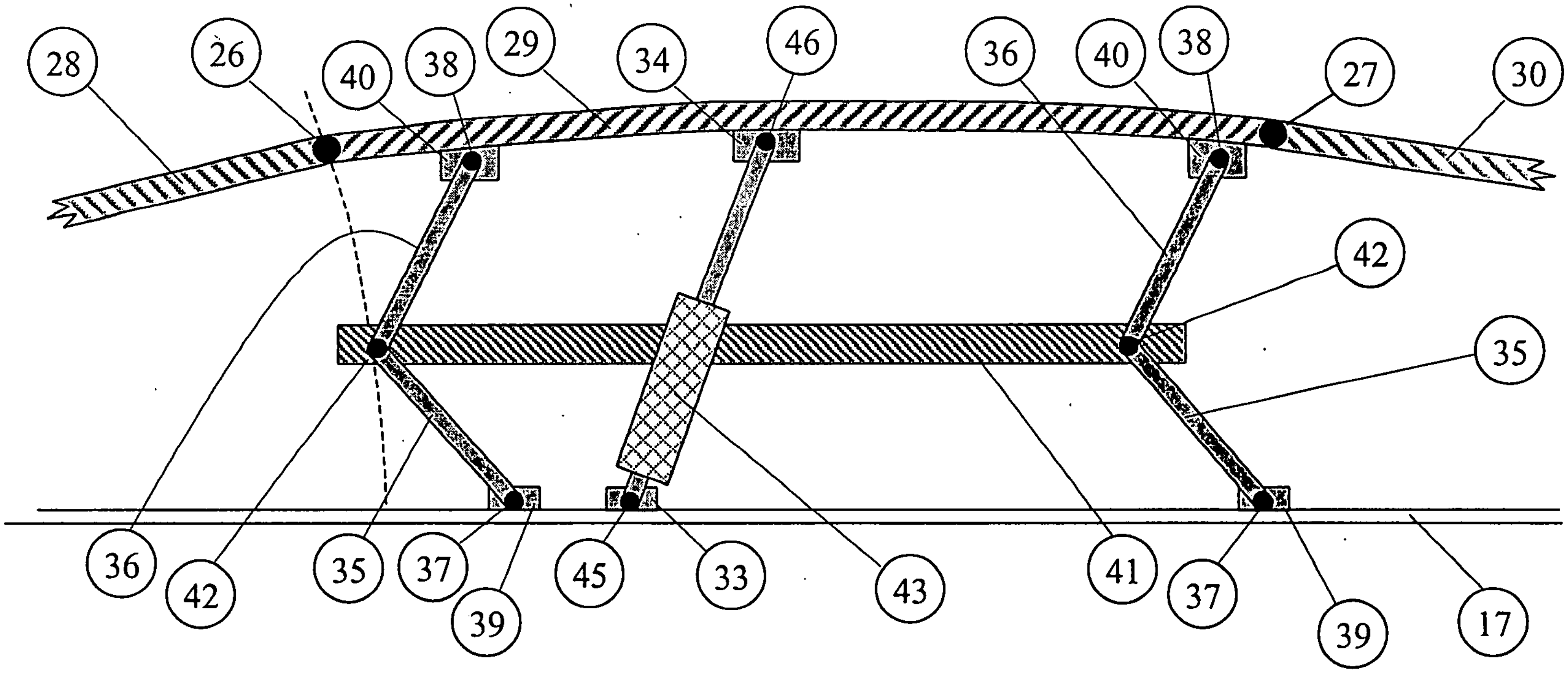

Figure 12

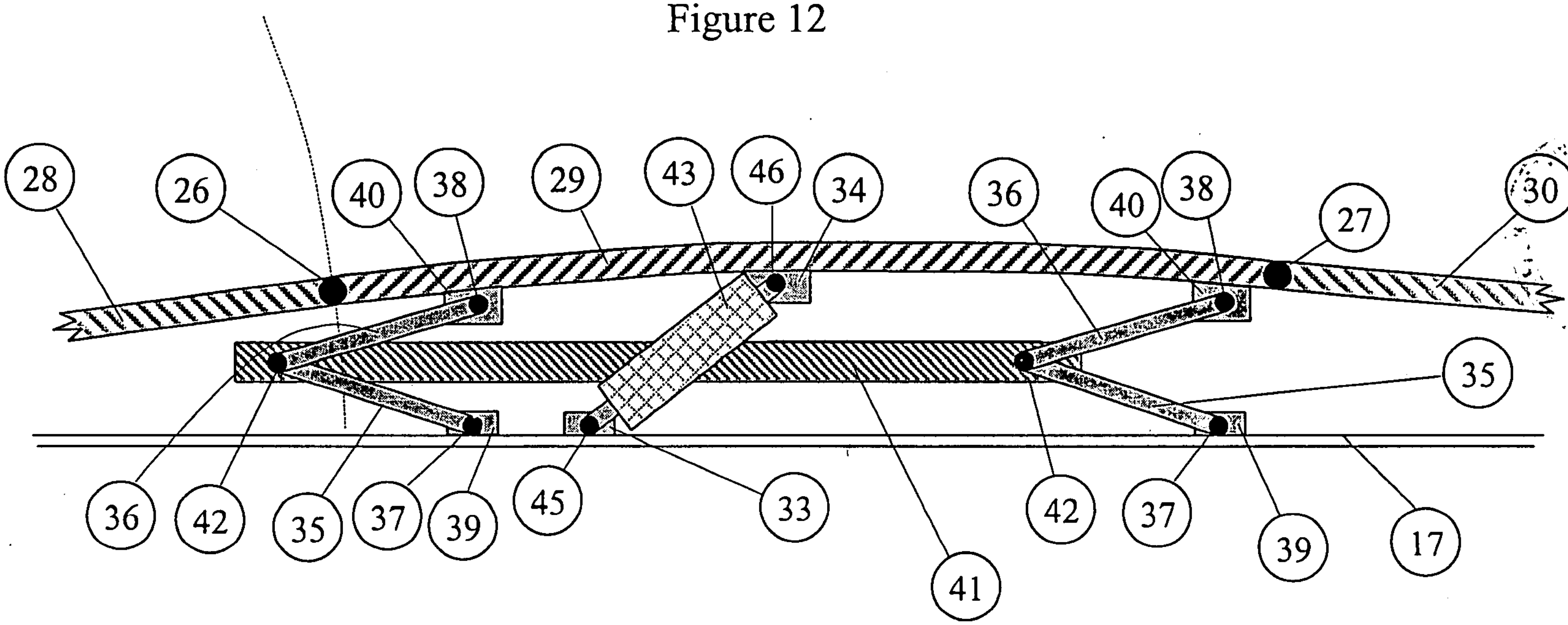

Figure 13

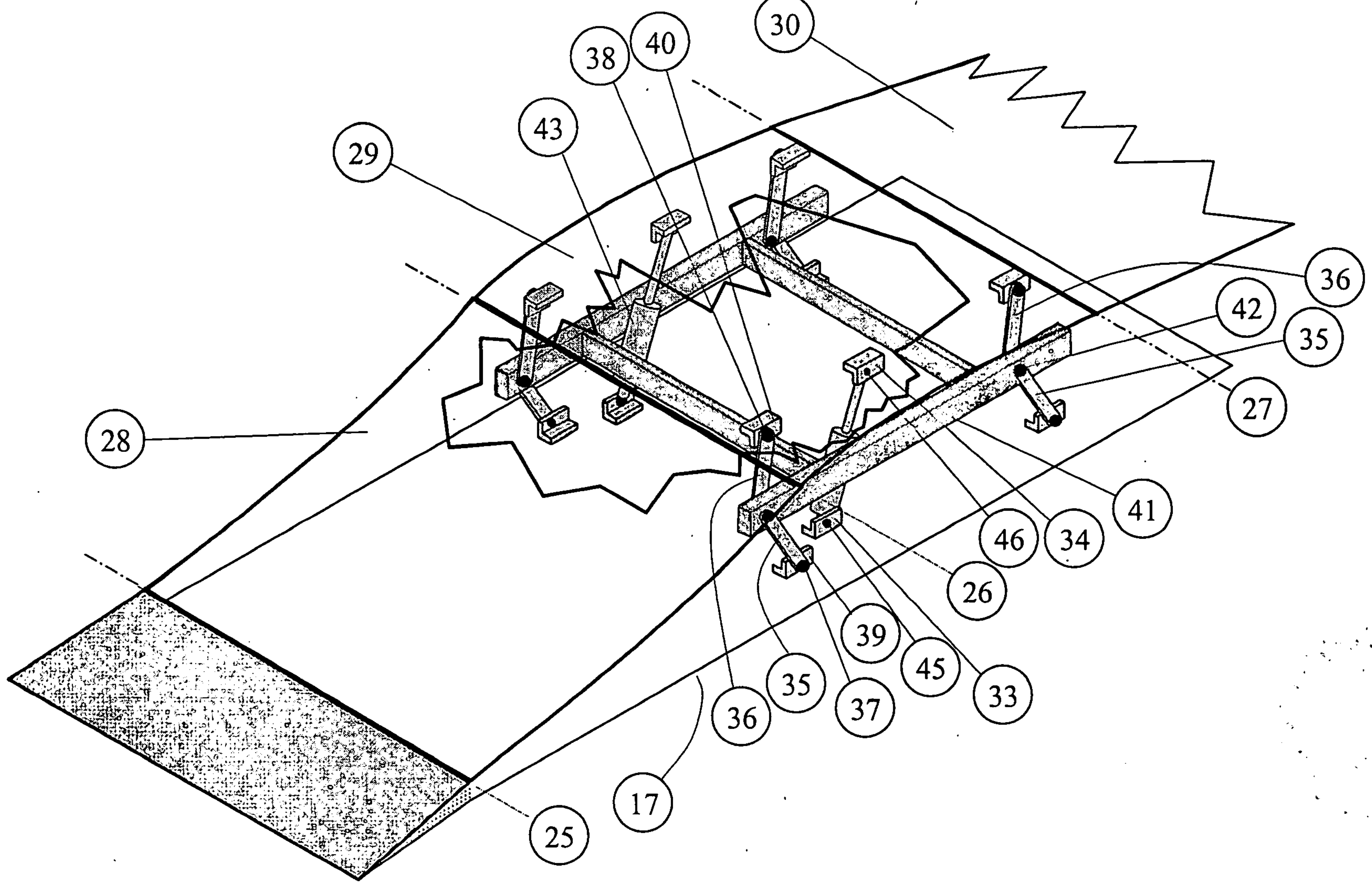

Figure 14

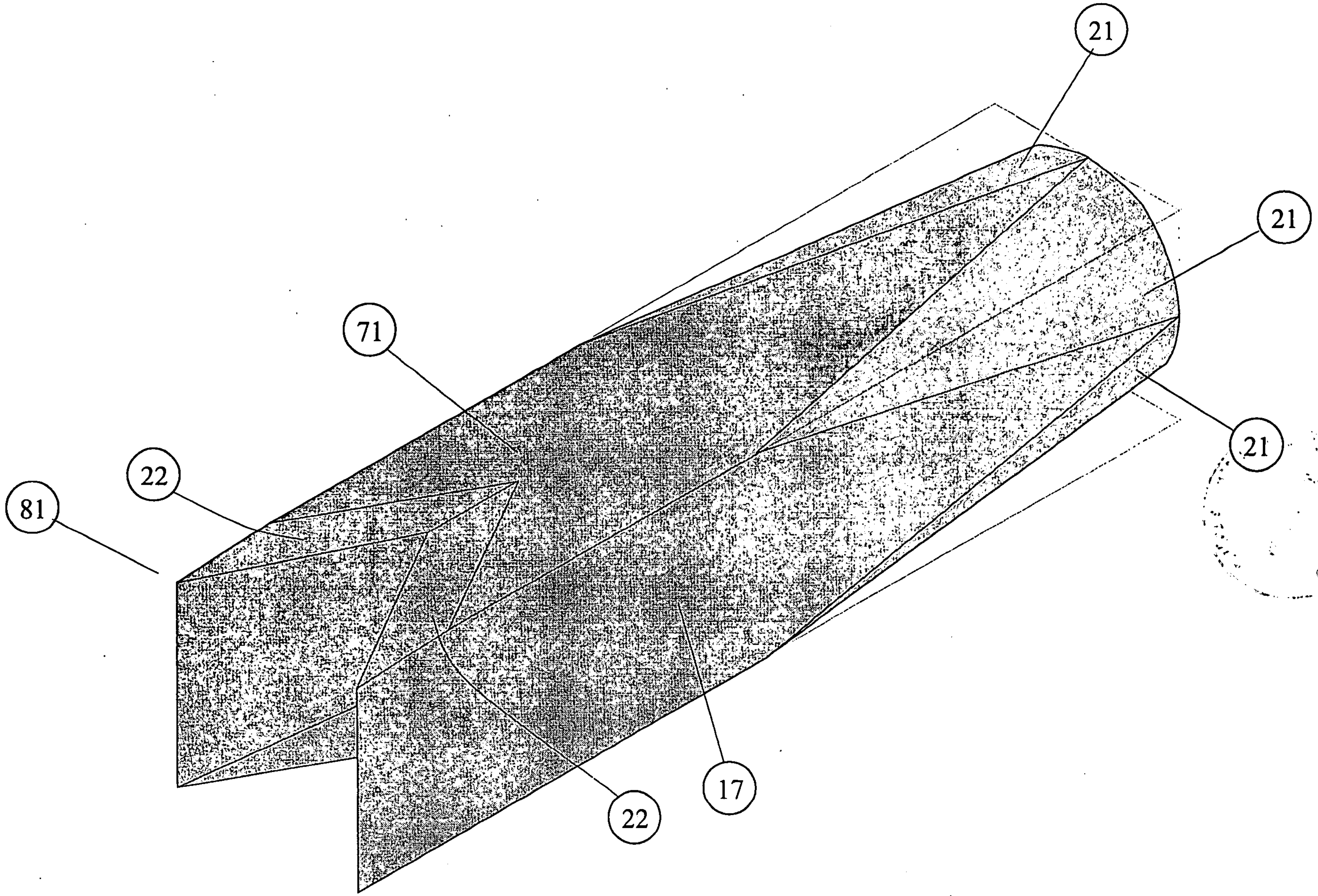

Figure 15

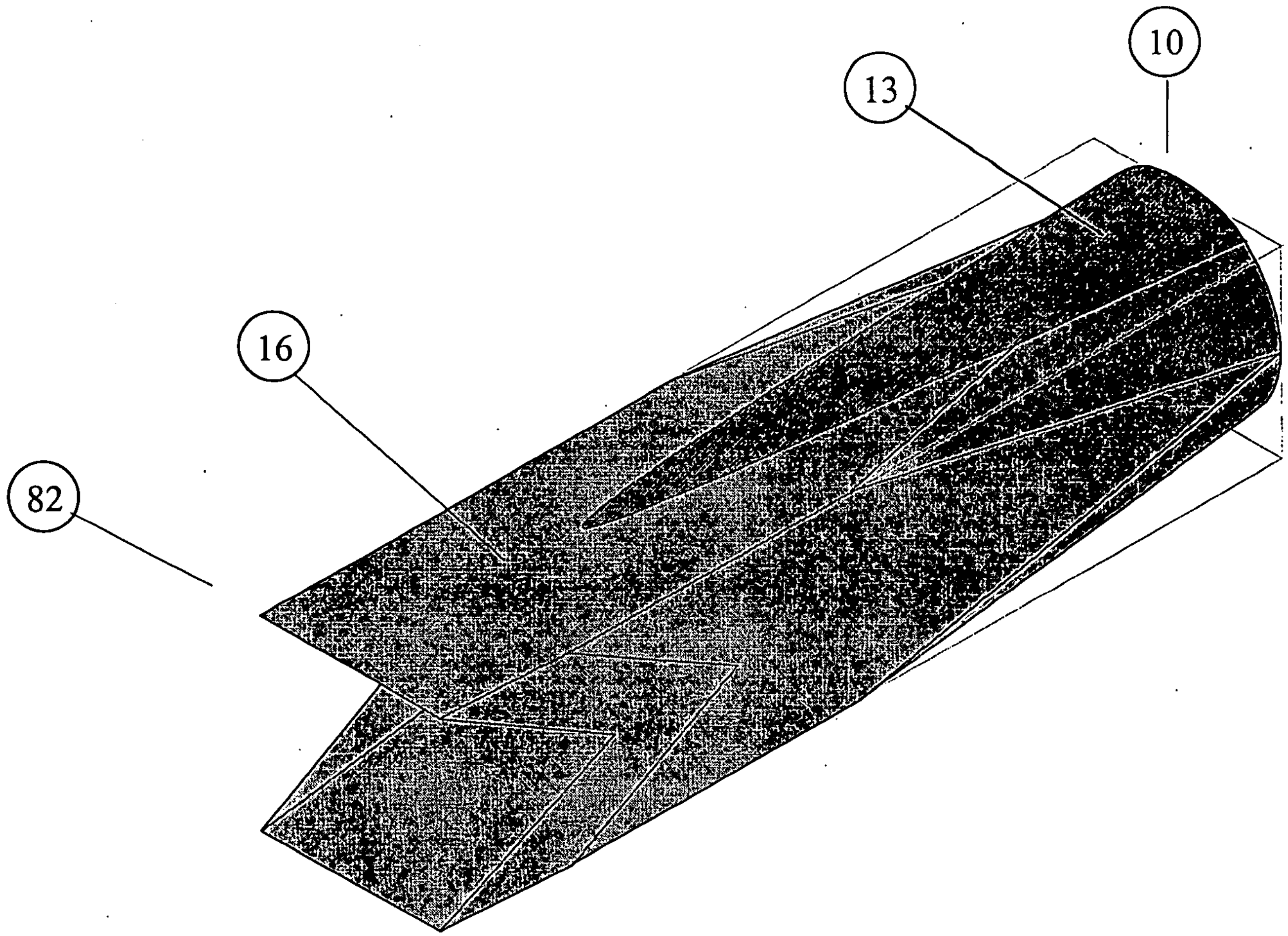

Figure 16

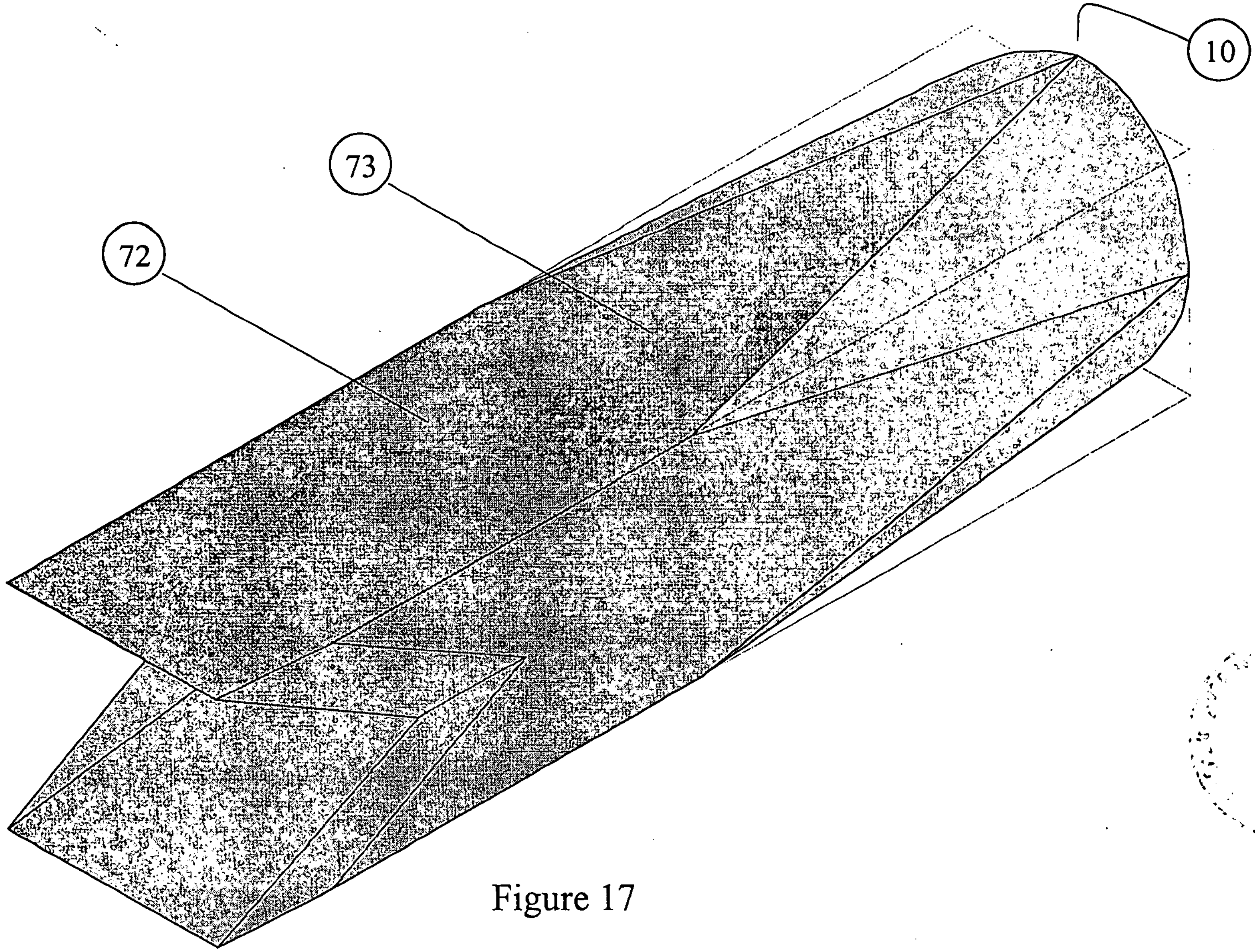

Figure 17

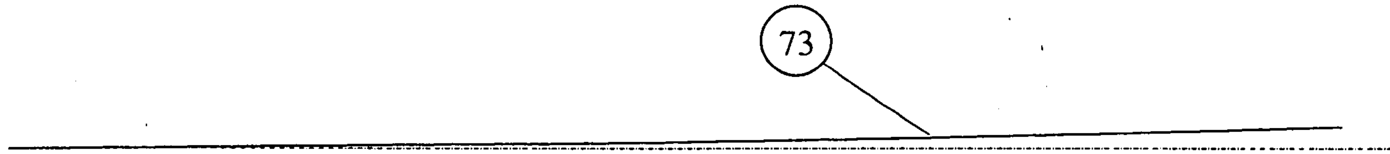

Figure 18

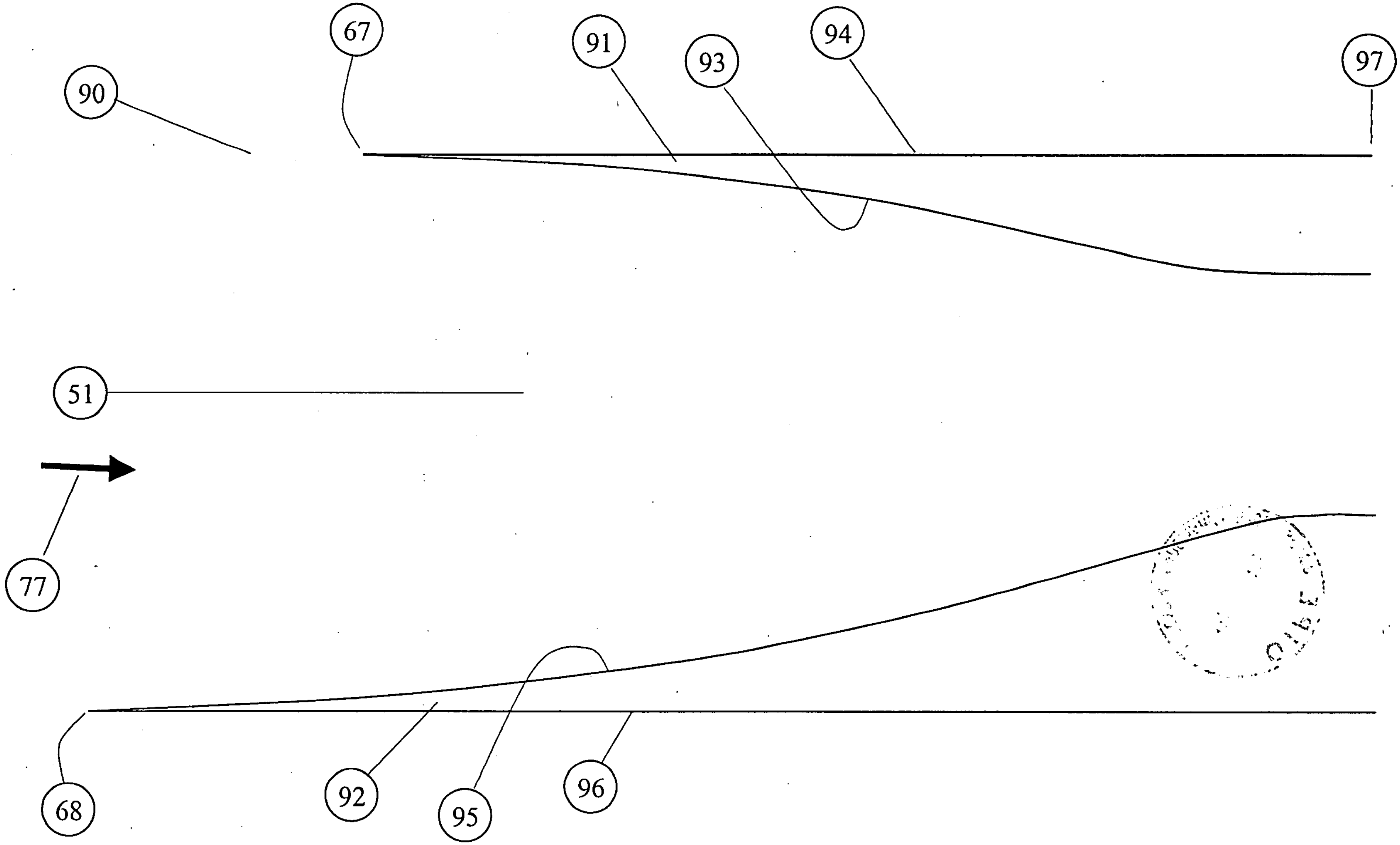

Figure 19

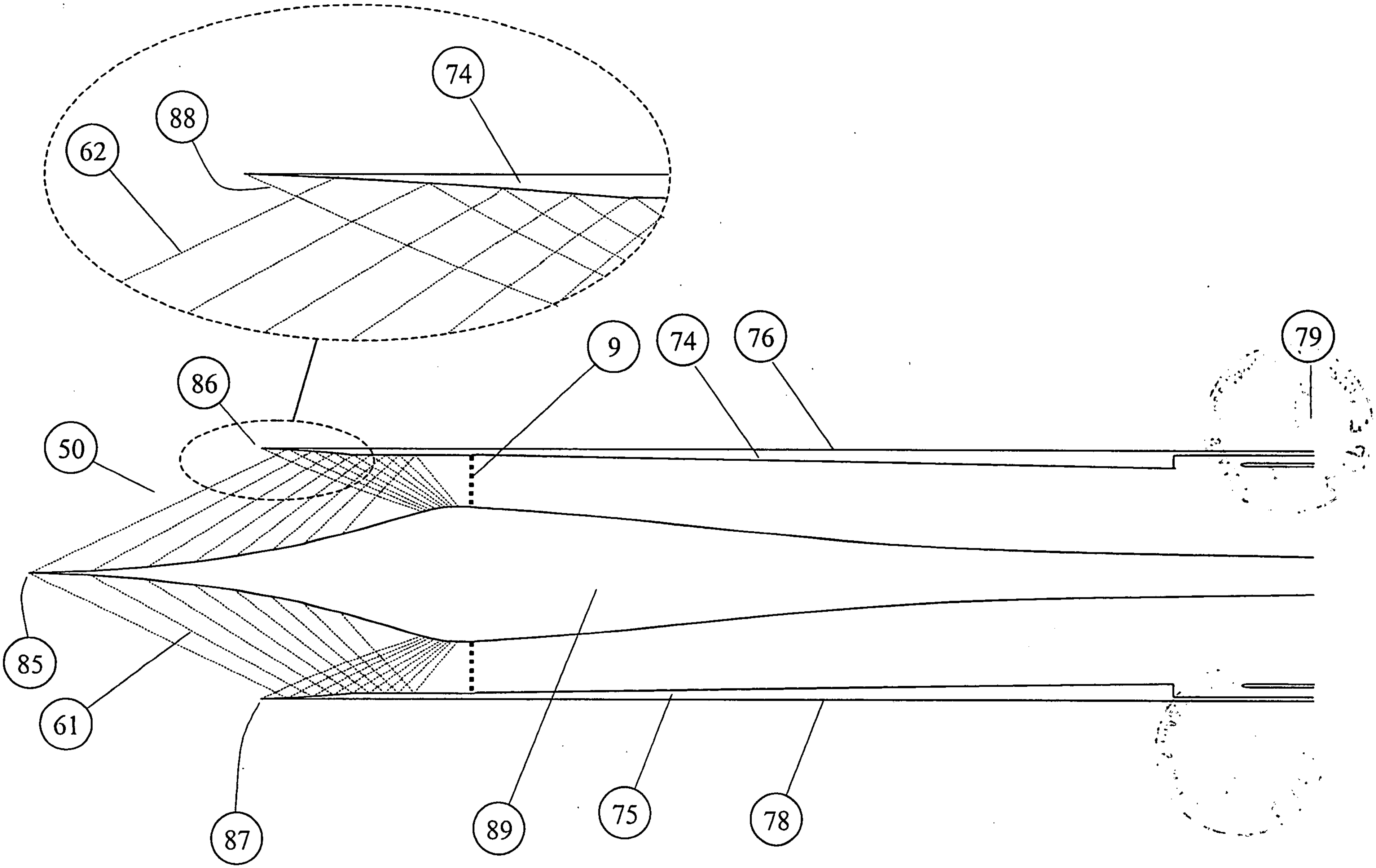

Figure 20

CALFEE, HALTER & GRISWOLD LLP

Docket No. 26272/04003

DECLARATION
AND POWER OF ATTORNEY

ORIGINAL APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT

the specification of which

☐ is attached hereto,
☒ was filed on September 26, 2001.
☐ and was amended on ____________________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim the benefit of foreign priority under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Country	Application Serial Number	Filing Date	Legal Status	Priority Claimed

I hereby claim the benefit of United States priority under 35 USC §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information material to

the patentability of this application as defined in 37 CFR 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial Number	**Filing Date**	**Legal Status**

I hereby claim the benefit of United States priority under 35 USC §119(e) of any United States provisional application(s) listed below:

Application Serial Number	Filing Date	Legal Status
60/235,359	September 26, 2000	Pending

I hereby appoint the following attorney(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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216-622-8200

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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	Date:____________________
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Citizenship	U.S.A.

Full name of second joint inventor:	Lois J. Weir
Inventor's Signature	______________________
	Date:____________________
Residence & Post Office Address	1306 Lipton Avenue, S.W. North Canton, Ohio 44720
Citizenship	U.S.A.

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Bonnie Harden-Mitchell
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Sanders, et al.

Serial No. 09/966,551

Filed: September 26, 2001

For: **LOW SONIC BOOM INLET FOR SUPERSONIC AIRCRAFT**

Attorney's Docket 26272/04003

Assistant Commissioner of Patents
Office of Petitions
Washington, DC 20231

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Declaration of Joyce Ford

1. I, Joyce Ford, was an administrative assistant to James A Rich, the attorney who prepared the above-mentioned patent application, on September 26, 2001.

2. During the normal business hours of September 26th, I prepared the following documents for the above referenced application: A Utility Patent Application Transmittal form; A Fee Transmittal Form, An Application Data Sheet and A return postal card.

3. In preparing these documents, I personally reviewed the patent application prepared by Mr. James Rich, the attorney who drafted the application. As instructed by Mr. Rich during normal business hours on September 26th, I edited the claims section of the application to incorporate Mr. Rich's revisions. Upon memory and belief, there were at least two pages of claims in the application.

4. In preparing the Utility Patent Application Transmittal form, I personally hand counted the total pages of the specification including claims and abstract, and drawings.

5. In preparing the Fee Transmittal Form, I reviewed the number of total claims and independent claims present in the application to ensure that no additional fees were due.

6. I hereby declare that all statements made hereon of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: May 23, 2002

Joyce Ford

Joyce Ford